EG HCF: Harmonization of Equipment Certificate Acceptance at European Level and Product Family Grouping

Final report for GC ESC approval

V 1.0

Revision Control

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Content

Revision Control 2

Nomenclature 7

1 Executive Summary 8

2 EG Background and structure 10
2.1 Terms of reference 10
2.2 Deliverables 11
2.3 List of participants 11
2.4 Timeline and course of meetings 13
2.5 Work structure and subgroups 13

3 Questionnaire on existing EU compliance processes 15
3.1 Objectives covered 15
3.2 Survey development 15
3.2.1 Insights needed 15
3.2.2 Methodology 16
3.2.3 Survey questions 16
3.2.4 Survey tool 17
3.2.5 Programming the survey 17
3.3 Distribution of survey 17
3.3.1 Target groups for the survey 18
3.3.2 Invite for submission 18
3.4 Received submissions 18
3.5 Conclusion of analysis 20

4 Family definition for PGU certificates 22
4.1 Introduction 22
4.2 Purpose of the Subgroup 22
4.2.1 Terms of Reference 22
4.2.2 Deliverables 22
4.3 Family Definition 22
4.3.1 Difficulties and Advantages 22
4.3.2 Existing Approaches 23
4.3.3 Common Points among Approaches 23
4.4 Family Definition Proposals 31
4.4.1 SPGU 31
4.4.1.1 Definition Proposal 31
4.4.1.2 Effects on main component changes 32
4.4.2 PPM – Rotating generation based PGU (non-wind) 34
4.4.2.1 Definition Proposal 34
4.4.2.2 Effects on main component changes 34
4.4.3 PPM – Wind power-generating unit (Wind PGU) 36
4.4.3.1 Definition Proposal 36
4.4.3.2 Effects on main component changes 37
4.4.4 PPM - Inverter based PGU (photovoltaic, battery or other non-wind) 39
4.4.4.1 Definition Proposal 39

4.4.4.2 Effects on main component changes ... 40
4.5 Transferability and Testing Scope within the Family ... 41
4.5.1 Active Power Controllability and Control Range ... 42
4.5.2 Reactive Power Capability and Control Modes ... 43
4.5.3 Dynamic Behaviour Capabilities ... 43
4.5.4 Other Capabilities ... 44
4.5.5 Capabilities Under Investigation ... 44

5 Simulation Model for dynamic verification ... 46
5.1 Introduction ... 46
5.2 Objectives covered ... 46
5.2.1 Terms of Reference and deliverables ... 46
5.3 Model definition ... 46
5.3.1 Overview ... 46
5.3.2 Models used in compliance processes ... 47
5.4 Parameters and settings ... 47
5.4.1 PGU/PGM Model parameters ... 47
5.4.2 PGU/PGM Settings ... 49
5.4.3 Electrical System parameters ... 49
5.4.4 Simulation Software Settings ... 50
5.5 Model validation process ... 50
5.5.1 Validation process ... 50
5.5.1.1 Tests used to validate specific logic control ... 51
5.5.1.2 Tests used to validate the behaviour of the generating unit ... 51
5.5.3 Model Validation process – Other validation methodologies used for specific studies ... 53
5.5.4 Extended validation with configurable settings ... 53
5.5.5 Model validity limits ... 54
5.6 Software to be used for validation ... 54
5.6.1 Software applicable for model validation ... 54
5.7 FRT capability using validated model / FRT characteristic transferability (different FRT characteristics) ... 55
5.7.1 FRT requirement types ... 55
5.7.2 FRT verification using tests ... 56
5.7.3 FRT verification using models ... 56
5.7.4 Transferability of the FRT capability considering different system conditions ... 57
5.8 Transferability of FRT capability to other similar PGUs ... 57
5.8.1 Transferability of the FRT capability among generating unit family member ... 58
5.8.2 Transferability of model and results from a simulation software to a different simulation software ... 58
5.8.3 Transferability of the result when the validation process is updated ... 59
5.9 Model validity and maintenance ... 59
5.9.1 Model maintenance ... 59
5.9.2 Model update associated to significant modernization ... 60
5.9.3 Model update due to software aging ... 60
5.9.4 Model update needed to verify new/additional requirements ... 60
5.9.5 Model updated due to plant changes that trigger new requirements for existing units ... 60
5.9.6 Maintenance of the model as part of manufacturer R&D activities for new generating unit ... 60
5.10 Encrypted Model / Black boxes ... 61
5.10.1 Certification process / model validation process ... 62
5.10.2 Encrypted model associated to different simulation software ... 62

6 Harmonized equipment certificate for Type A ... 62

6.1 Introduction ... 62
6.2 Objectives covered ... 63
6.2.1 Terms of Reference ... 63
6.3 Issues with Type A harmonization ... 63
6.3.1 Requirement reference: from PoC to unit terminals ... 63
6.3.2 Country-specific threshold values ... 63
6.4 Proposal for a harmonized certificate for Type A PGUs ... 64

7 Harmonized approach for certification acceptance at EU level ... 67
7.1 Introduction ... 67
7.2 Objectives covered ... 68
7.2.1 Terms of Reference ... 68
7.3 PGU-, component- and PGM-certification – a classification approach ... 69
7.3.1 Power-generating unit (PGU) certificates ... 69
7.3.2 Component certificates ... 69
7.3.3 Power generating module (PGM) certificates ... 70
7.4 Formal Requirements on Equipment Certification ... 71
7.4.1 Formal Framework – The ISO/IEC 17065 standard on product certification ... 71
7.4.2 The central role of the certification scheme ... 72
7.4.3 General Structure & Content of PGU & Component Certificates ... 73
7.4.4 Product Series of Equipment for Certification – Family Definition ... 75
7.4.5 Validated PGU & Components Simulation Models ... 75
7.4.6 Selective Certificates ... 75
7.4.7 Validity of Certificates – Modification in Hard- & Software ... 75
7.5 Status Quo on EU Equipment Certification and International Outlook ... 76
7.5.1 International Outlook ... 76
7.6 Specified Requirements – Opening different Pathways of PGU and Component Certification ... 77
7.6.1 The Standard Approach – National Grid Code Certification ... 77
7.6.2 Generic Approaches for Umbrella Certification ... 78
7.6.2.1 Certification with respect to RfG ... 78
7.6.2.2 Certification with respect to EN 50549-1/-2 ... 79
7.6.2.3 Capability Certification ... 80
7.6.3 Overview ... 81
7.7 Scheme on Prototype Definition & Prototype Declaration ... 81
7.8 Recommendations on Measures to Increase the Acceptance of PGU & Component Certificates ... 82
7.8.1 Definitions on the general formal background ... 82
7.8.2 Requirements as specified by the relevant system operator ... 83
7.9 Pathways to PGMD and Compliance Schemes on PGM Level by applying Equipment Certificates ... 85

8 References ... 87

Annex I: Analysis of responses from Survey ... 89
1.1 General information and legislation ... 89
1.2 Process - Conformity assured by scheme for type approval (general product test) - primarily Type A ... 94
1.3 Compliance reports on Power Generation Unit and component level ... 98
1.4 Compliance documentation on Power Generation Unit and components thereof - Equipment Certificates ... 101
1.5 Documentation at installation site – commissioning ... 106
1.6 Additional questions ... 117

Annex II: Detailed analysis of requirements at unit terminals ... 121

1.1 Detailed analysis of Type A requirements (RfG, Article 13, "General requirements for type A power-generating modules") 121
1.2 Detailed analysis of Type B requirements (RfG, Article 14, "General requirements for type B power-generating modules") 122
1.3 Detailed analysis of Type C requirements (RfG, Article 15, "General requirements for type C power-generating modules") 123

Nomenclature

Abbreviation	Description
A.C.	Alternating Current
ACPGM	Additional Component of the PGM
AVR	Automatic Voltage Regulator
CP	Connection Point
EG	Expert Group
EqC	Equipment Certificate
FFCI	Fast Fault Current Injection
FRT	Fault Ride Through
GU	Generation Unit
HMI	Human Machine Interface
NC RfG	Network Code Requirements for Generators
NRA	National Regulation Agency
OVRT	Over Voltage Ride Through
PGF	Power Generating Facility
PGM	Power Generation Module
PGMD	Power Generation Module Document
PGS	Power Generation System
PGU	Power Generation Unit
PMG	Permanent Magnet Generator
PoC	Point of Connection
POD	Power Oscillation Damping
PPC	Power Plant Controller
PPM	Power Park Module
RSO	Responsible System Operator
Simulations	Refers to “compliance simulations”
SG	Subgroup
SPGM	Synchronous Power Generation Module
SPGU	Synchronous Power Generation Unit
UVRT	Under Voltage Ride Through

*Definitions shall be as defined in [10] when applicable

1 Executive Summary

According to the Regulation 2016/631 (NC RfG), equipment certificates (EqCs) can be used to show compliance of a PGM against the requirements found in a grid code. The IGD "General Guidance on Compliance Verification – Compliance Testing and Use of Equipment certificates" [9] has further elaborated a framework on how to apply EqCs within the compliance process on PGM level. Many EU member states have defined their own definitions of certification. Some member states accept EqCs from other member states which have been issued by accredited authorised certifiers if the accreditation and further certification process took place within the Regulation (EC) No 765/2008. In this regard, an EU harmonized equipment certificate would help ensure that equipment, processes, and services are safe, reliable and comparable. It also helps to promote fair competition within the EU, by ensuring that all equipment, processes, and services sold within the EU meet the same standards, regardless of where they are manufactured or provided. In addition, an EU harmonized equipment certificate can serve as a mark of quality and reliability for consumers and grid operators, as it demonstrates that the equipment, process, or service has been thoroughly tested and meets the high standards set by the EU.

To achieve EU harmonized equipment certification, the following aspects are important:

1) Clarification of PGU and PGM concepts leads to intensive discussion. This critical issue is not always clearly defined or understood.

   EG HCF came to the conclusion that only PGU and component certificates can be harmonized on EU level to facilitate the proof of compliance on PGM level. These certificates are based on type testing of the PGU or the component. They may cover the entire range of grid connection requirements or only parts of them.

   PGU certificates can be used as part of the compliance process specified in the NC RfG [10] to demonstrate compliance at the PoC (this includes the use of a PGMD). Irrespective of the unit certificate issued based on the recommended certification scheme, TSO/DSOs will keep the right to require additional compliance simulations or on-site compliance testing, based on the frame requirements specified in the NC RfG.

2) Each member state has their own choice to define a PGM compliance assessment based on an EU harmonized PGU certificate; this could be achieved either through a certification process at PGM level using the PGU certificates, or by accepting a PGMD (or similar document) coming from a PGF owner based on the content of the PGU certificate and additional site-specific testing and simulations.

   EG HCF identified different approaches in different nations, but no standardized approach was seen.

3) The implementation of PGMDs (or similar documents) can be the key link between PGU compliance assessment at PGU terminals (PGU certification) and the PGM compliance in regard to the PoC.

   Nevertheless, PGMD definition in the NC RfG is restricted to type B and C. It is recommended to create new expert groups and extend the PGMD concepts to type A and type D. The complexity of PGMDs is based on national definition and PGM size.

4) A family definition applies to a group of related products that share common characteristics or features coming from a same manufacturer.

   A product family definition typically includes information about the common points that define the product family, as well as the intended use or purpose of the products within the family. Transferability of test results from one of the family members to the rest depend on the requirements and technology.

Based on technical investigations and discussions, the EG HCF suggests having a family definition per design technology which is manufacturer based, regardless of power range and voltage level.

5) The Simulation model is a powerful tool to evaluate PGM performance without additional costs and time intensive testing.

   The PGU simulation model shall correctly represent the structure of the unit and shall be considered reliable when the simulation outputs have been validated against testing results (e.g. real test values, laboratory tests). The model should be part of the PGU certificate

   On a project level, this model shall be used within the overall facility simulation model which shall correctly represent the structure of the system/module/unit including the system parameters that describe the required country settings (according to the national implementation of the NC RfG).

6) Different approaches for component and PGU level certification (individual or family) are provided including three proposals for umbrella certificates. A promising approach for harmonizing certification on EU level may be provided by a “capability certificate” that can easily be enhanced by grid code specific conformity statements.

7) Any authorised certifier issuing certificates on products, services and processes must hold a valid accreditation with respect to the standard ISO/IEC 17065 which gives the general framework for product certification and is in general provided by the authorised certifier’s national accreditation authority. Given this framework, the certification scheme according to ISO/IEC 17067 plays a significant role for the entire certification processes. Any certificate must uniquely reference the underlying certification programme. EG HFC strongly recommends applying the existing and well-established programmes.

2 EG Background and structure

On the 22nd of September 2021, the Grid Connection European Stakeholder Committee (GC ESC) has decided to establish an expert group on Harmonization and acceptance of equipment certificates and product family grouping.

Since the publication of NC RfG, all member states have adopted the ENTSO-E guidelines and have defined accordingly a compliance process including testing and equipment certification. The practical implementation proves that the certification process is a good method to ensure grid code compliance before connection. However, each nation has an individual approach, thus the manufacturers of type tested, mass produced products are obliged to involve themselves in repeating tests and certification processes in different nations that can prove both time consuming and expensive, having a negative impact on project plausibility and causing considerable delays to connection permission. Nevertheless, additional FRT test permissions are difficult to obtain from local grid operators, especially when a manufacture is located in a EU member state where less stringent FRT requirements exist but more stringent FRTs need to be tested according to other EU member states.

2.1 Terms of reference

The terms of reference were approved by the GC ESC on the 7th of December 2021.

The initial tasks of the EG were to:

1. Clarify various types of certification definitions, e.g. equipment certificate, component certificate etc.
2. Understand the existing EU schemes on proof of compliance which includes:
   - Certification requirements and specifications applicable in the member states (including certification, test procedures and test validation criteria, model requirements and model validation criteria). e.g. Germany FGW TG8, CEO 0-16 Annex Nter, EN_NormaTecnicaSupervision631_v2.1
   - International Standards regarding certification including
     - ISO 17025 General requirements for the competence of testing and calibration laboratories,
     - ISO 17065 Conformity assessment - Requirements for bodies certifying products, processes and services,
     - ISO 17067 Conformity assessment - Fundamentals of product certification and guidelines for product certification schemes
   - Existing schemes for conformity with EU-Directives in other fields, such as the new legislative framework for the CE-Directives.
   - Draft EN 50549-10 Requirements for generating plants to be connected in parallel with distribution networks — Part 10: Tests for conformity assessment of generating units, especially clause 4.4 Configuration range and parameter sets
   - Existing and currently developed schemes in IEC RE WG10,
   - Taking into account the provisions of ENTSO-E IGD: General guidance on compliance verification – compliance testing and use of equipment certificates (July 2021)

Based on a common understanding of the items listed above, the objective of the EG is to:

1. Provide a path for the creation of EU harmonized testing strategies and proof of compliance methods as well as a proposal on key criteria to meet requirements in RfG, taking into account existing strategies in other sectors of EU regulation.
2. Define an approach to accept certificates at EU level for all types (A, B, C and D). This can include a set of minimum requirements on respective statements of conformity, including the option of only selective conformity and the application of component certificates.
3. Define a common product family definition and grouping criteria for an equipment certificate.

4. Provide a path for a harmonized European approach to accept validated simulation models and define their recommended scope of use to substitute equipment testing.

2.2 Deliverables

The following deliverables were defined:

- Report about existing certification schemes and other schemes on proof of compliance in member states
- Recommendation on testing scope and family grouping definition (including definition and usage of validated models)
- Recommendation on certification specification and procedure (including criteria for the acceptance of existing certifications that cover NC RfG requirements on EU countries)

2.3 List of participants

The following nominations to participate in this EG were received (name and association):

Table 1 EG HCF Participants

Name	*Organisation*	*Representation at GC ESC*
Adrián González González	ENTSO-E	ENTSO-E
Alessandro Zuccato	CENELEC	Kiwa Creiven srl
Alexandra Tudoroiu	COGEN Europe	COGEN Europe
Andres Pinto-Bello	smarten	smarten
Annette Jantzen	EUGINE	EUGINE
Assiet Aren	EUGINE	MWM/Caterpillar Energy Solutions
Bernhard Schowe-von der Brelie	VAZ	FGH
Caoimhín Ó BRIAIN	EURELECTRIC	EURELECTRIC
Carsten Junge	WindEurope	GE Renewable Energy
Dirk Rahn	EFAC	Moeller Operating Engineering GmbH
Florentien Benedict	CEDEC	Stedin
Freddy Alcazar Barrientos	EUGINE	INNIO
Giuseppe Dell'Olio	CENELEC	GSE SpA
Juan Pena de Juana	SolarPower Europe	SMA
Keith Chambers	Europgen	Caterpillar
Laurent Schmitt	smarten	Dcbel
Luca Guenzi	EUTurbines	Solar Turbines
Luigi D'Orazio	EURELECTRIC	e-distribuzione
Marc Malbrancke	CEDEC	CEDEC

Markus Holzapfel	WindEurope	Vestas
Maxime Buquet	EUTurbines	GE
Mike Kay	ENA	GEODE
Roland Bründlinger	EASE	AIT
Rong Cai	WindEurope	Hitachi Energy
Sergio Martinez Villanueva	ENTSO-E	REE
Søren Stig Abildgaard	COGEN Europe	EC Power
Srinivasa Raju Addala	EUGINE	Wärtsilä
Steffen Eckstein	EUTurbines	Siemens Energy
Sudharsana Govindaswami	CENELEC	Cummins Power Systems
Volker Schulz	ENTSO-E	Amprion
Xabier Calvo	COGEN Europe	Ingeteam Indar Machines
Yatin Bisne Prakash	WindEurope	Siemens Gamesa
Tobias Gehlhaar	N/A (supported the EG with certifier expertise)	Germanischer Lloyd Industrial Services GmbH
François Colet	SmartEN	Dcbel
Nils Schaefer	CENELEC	Fraunhofer IEE
Sebastien Dennetiere	ENTSO-E	RTE
Giovanna Tanda	EUTurbines	EUTurbines

The following participants left the working group before the finalisation of the work:

Table 2 EG HCF Former Participants

Name	*Organisation*	*Representation at GC ESC*
Doina Ilisiu	ENTSO-E	Transelectrica
Eckhard Schwendemann	CENELEC	ES-TMC
Ioannis Theologitis	ENTSO-E	ENTSO-E
Magdalena Kurz	EUTurbines	EUTurbines

The following main contributors helped lead the work of the EG:

- Freddy Alcazar Barrientos – Chair & Subgroup leader
- Assiet Aren – Vice Chair
- Annette Jantzen – Organization and group administration
- Søren Stig Abildgaard – Subgroup leader
- Luca Guenzi – Subgroup leader
- Giuseppe Dell'Olio – Subgroup leader

- Bernhard Schowe-von der Brelie – Subgroup leader

2.4 Timeline and course of meetings

The EG was initially planned with an approximate duration of one year, but due to the complexity of the different topics and the need for a longer internal review time, the total time was extended by 2 months (approved in 28th GC ESC on the 30th of November 2022.

The work was structured in monthly meetings (as a minimum), with additional meetings scheduled as the need was observed. The following meetings were held

Table 3 EG HCF General Meetings

Date	Description
15 December 2021	Kick-off meeting: approval of the ToR, discussion on work organisation and timing
20 January 2022	General meeting: final approval of ToR, discussion on certificate types, discussion on scope of sub-groups
22 February 2022	General meeting: discussion on certificate types, status of sub-groups
22 March 2022	General meeting: status of sub-groups, discussion on PGU vs PGM
26 April 2022	General meeting: administrative points, status of sub-groups, discussion on PGU vs PGM
24 May 2022	General meeting: status of sub-groups, extended discussion on sub-groups
21 June 2022	General meeting: status of sub-groups, discussion on general workplan and deadlines for deliverables
8 September 2022	General meeting: status of sub-groups, general workplan and deadlines for deliverables
5 October 2022	General meeting: status of sub-groups
9 November 2022	General meeting: status of sub-groups
24 November 2022	General meeting: status of sub-groups, decision on prolongation of work
14 December 2022	General meeting: status of sub-groups, status of final report
25 January 2023	General meeting: discussion of Final Report
8 February 2023	General meeting: discussion of Final Report

2.5 Work structure and subgroups

Due to the extent of the scope of the EG, the work was divided in 5 sub-groups (SG) as follows:

- SG1: Questionnaire for existing EU compliance processes (Led by Søren Stig Abildgaard)
- SG2: Simulation model for FRT to be used at EU level (Led by Luca Guenzi)

- SG3: Harmonized approach for equipment certificate for Type A (Led by Giuseppe Dell'Olio)
- SG4: Harmonized approach for certification acceptance (definition of types and testing) (Led by Bernhard Schowe-von der Brelie)
- SG5: Family definition (Led by Freddy Alcazar)

This report is a compilation of the outcome of each of the subgroups (each of which provided a corresponding sub report).

3 Questionnaire on existing EU compliance processes

The Network Code Requirements for Generators (NC RfG) of the EU commission set out harmonized rules for grid connection for power-generating modules. The aim is to ensure stability of operation and a high level of security of electricity supply as the EU internal market of electricity develops – with the integration of distributed renewable sources, increased (and fair) competition for electricity services.

The NC RfG specifies, that it is the duty of the generation owner to ensure that connected power-generating modules comply with rules specified within and gives responsibility for the assurance of compliance to the network system owner. However, the NC RfG does not include much direction on how those rules should be enforced, and it only defines general rules on how compliance of power generating modules should be demonstrated without precise requirements. It is instead the task of the single Member State, the NRA or the network companies within that state, to specify their national compliance and certification programs – with the approval of the NRA.

This Expert Group was established to investigate the possibilities of harmonizing the certification systems of power-generating modules and parts thereof. A harmonised certification system would support the internal market for power-generating modules as such and at the same time support the fair and transparent enforcement of NC RfG rules.

As a first step this Expert Group wanted to understand the current certification systems in place in each Member State and how it is applied to all types of power-generating modules.

The Expert Group therefore developed an online questionnaire, which was distributed to system operators, testing and certification bodies and the manufacturers of generators and any other stakeholders. With the knowledge gathered, the Expert Group should be better informed to develop meaningful proposals that recognizes the practices already deployed in member states within the scope of the NC RfG.

The EUSurvey page for contributions will remain accessible until December 2023 by following this link: https://ec.europa.eu/eusurvey/runner/RfG_CertificationSurvey2022

Received data from all submissions (personal information excluded) are accessible by following this link: https://ec.europa.eu/eusurvey/publication/RfG_CertificationSurvey2022 password: EG-HCF

3.1 Objectives covered

According to the terms of reference (ToR) [1], the following objective is covered within this section:

"Understand the existing EU schemes on proof of compliance"

3.2 Survey development

The subgroup I has developed survey within the electronic EUSurvey tool. A pdf version of the full survey is available in annex I.

The development of the survey is presented below.

3.2.1 Insights needed

The task of this subgroup and aim of the survey was

> *to understand the compliance and certification programs in place in each Member State and how it is applied to each type of power-generating module.*

With this information gathered, the goal was

> *to identify, where there are similarities between the used compliance and certification programs.*
>
> *to identify consensus – examples where most Member States have chosen similar steps.*
>
> *to identify best practice.*

3.2.2 Methodology

As a starting point we know that RfG is implemented very differently between Member States. It is therefore a first priority for this survey to capture evidence of each implementation as it appears in its own right.

Instead of forcing closed questions on survey participants, we make use of open questions that leaves more room for the participant to answer in a way that is meaningful in their specific circumstances. The drawback of open questions is that answers are not automatically comparable, but instead need further analysis before there is useful information.

With the information gathered from survey participants, it is our aim to carry out the analysis in order to organize and finally compare the certification systems. This work should result in new insight that should assist the further work of this Expert Group to develop meaningful proposals.

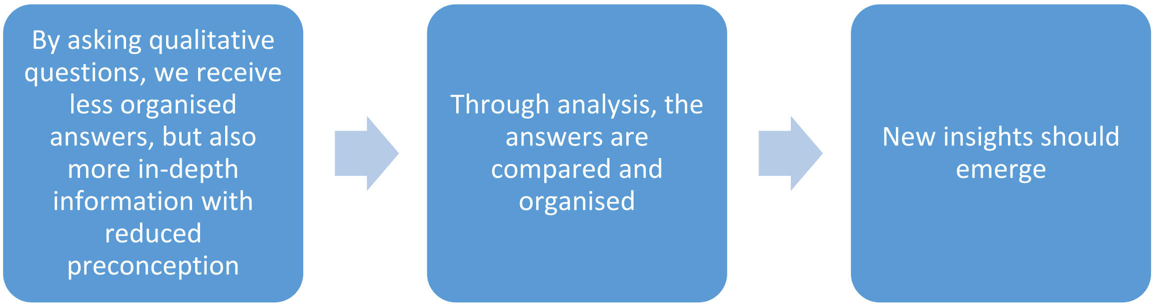


Figure 1 process of survey and analysis

3.2.3 Survey questions

As it is also indicated above, it may not be possible to compare two compliance and certification programs directly, and similarly, a question that can be readily answered within the framework of one certification program, may not be meaningfully answered within the framework of another certification program.

From this followed the below considerations before writing our survey questions.

Table 4 Development of survey questions

Considerations before writing our survey questions	Means to adapt the questionnaire
There is no obligation from the participant to respond to the survey and no direct benefit, so we depend on the willingness from each participant to spend time on answering the questions.	The questionnaire needs to be easy to respond to. Make use of a trustworthy and easy to use survey tool.
To get best picture of each implementation of RfG, we need to capture evidence of each implementation as it appears in own right.	The questions must in general be open. For example, by asking the participants to write their own answers instead of using multiple choice with predefined answers.
It must be expected that not all questions can be answered meaningfully by all survey participants.	Highlight in the survey, that the respondents should just answer questions that appeared meaningful to them.
Survey responses must be divided into the two dimensions of Member States and generator type.	For each submission, the respondent must declare the country and the generator type for which the answers apply.

The survey questions are the questions within paragraphs 3.1 to 3.6, found in appendix 1.

3.2.4 Survey tool

We have used the online survey tool from EUSurvey | ISA (europa.eu)

EUSurvey is supported by the European Commission's ISA programme, which promotes interoperability solutions for European public administrations.

The survey tool is well developed with many features for programming a both elaborate and presentable questionnaire.

With the tool, it was possible to build and distribute the questionnaire and then to collect and analyse the data – all electronically. Also, the tool can be configured to properly assist the data management within the rules of GDPR.

The tool was found to be a very useful match to our needs.

3.2.5 Programming the survey

The survey is programmed with 5 pages that can always be viewed at the top of the survey page as shown in the figure below. This helps the contributor to keep an overview.

Figure 2 Pages found within the survey

Each page then includes a part of the survey, with the page case data containing the primary questions.

Table 5 Survey page description

Start	Contact information of the contributor
Organisation	Details of the organisation, the contributor is representing. This information helps to understand the perspective of the contributor and to adapt the survey questions where possible (programmed into the survey).
Case selection	Details of the case for the particular submission, including country and generator type A/B/C/D. This information is needed to group the answers.
Case data	The actual survey questions named above, 3.1 to 3.6.
Submission	Submission with the possibility to enter a new submission for another case

3.3 Distribution of survey

A draft survey was first tested among the subgroup members. This initial test allowed us to test the survey tool, to test the questions and to test if the answers could be used meaningfully.

After the initial test and the final edits, the survey was distributed to the target groups.

The EUSurvey page for contributions will remain accessible until December 2023 by following this link: https://ec.europa.eu/eusurvey/runner/RfG_CertificationSurvey2022. This is to allow interested readers to view the survey as it was distributed to the contributors.

Note: It is possible to add new contributions, but they will not be used.

3.3.1 Target groups for the survey

There are many parties involved in the compliance and certification programs. Each party has a specific stake in the process. No party has the full picture. To understand the compliance and certification programs we therefore need to collect answers from all parties that are involved in the process. The different parties do not add a new "dimension" to the survey, but they represent potentially different views.

Country: All countries who relates themselves to the NC RfG

Regional institutions: All institutions involved in drafting and/or administering the Grid codes. Naturally, those should have information on the process for equipment approvals. They include DSO's and TSO's.

Manufacturers: Manufacturers who are seeking prof of compliance for their generator equipment. Those manufacturers will have experience and practical knowledge of the process to reach approvals in the regions where they operate, and for the specific products they manufacture. Although each manufacture will have only case-specific experience, it could be valuable information to get the full picture of (and validate) the compliance process in each country. In the list, the manufacturers should be named for the countries where they operate.

Certification and testing bodies: The certification bodies could present yet another view on the compliance process. Most interesting are bodies that already do equipment certification according to NC RfG, however, other certification bodies who we could expect to do NC RfG compliance testing are also of our interest. In the list, the certification bodies should be named for the countries where they are based, and also where they have experience in NC RfG compliance certification.

3.3.2 Invite for submission

The survey tool from EUSurvey gives different possibilities for invites:

- The survey tool is programmed to send direct invite to possible participants.
    - When the direct invite was used, the invitation was accompanied with a letter explaining the survey.
- A published survey link is sent by mail to possible participants
    - When the published survey link was used, the sender would present the survey.

Invitations have been sent to each TSO.

Since the number of DSO's is very high, we have instead looked for a DSO business association (GEODE) with a hope for them to distribute the survey. Also, business associations for manufacturers have been included.

Table 6 Directly invited entities

Invited TSO's	IPTO SA, Amprion, APG, AST, Ceps, Eirgrid, Elia, Elektromreža Srbije, Energinet, Fingrid, Hops, Litgrid, Mavir, National Grid, Noshib, PSE S.A., Redeia, Ren, Réseau de Transport d'Électricité, Seps, Statnett, Svenska kraftnät, Swissgrid, Tenne-t, Terna, Transelectrica
Invited business associations	Cedec, Eugine, EUTurbines, Entso-e, Eurelectric, Smarten, Cogen Europe

3.4 Received submissions

Received data from all submissions (personal information excluded) are accessible online by following this link: https://ec.europa.eu/eusurvey/publication/RfG_CertificationSurvey2022

Note: use the password EG-HCF

In total, we received 25 submissions. This is not enough to know the NC RfG implementation in all Member States, but it is still 25 different views with very useful information.

Although we sent individual invitations to all TSO's, we have received only three submissions from here (Romania, Spain and Poland) but those from Poland were not taken into account due to being received after the analysis of data had been completed. Therefore, the coverage from TSO's is limited.

Which of the following roles would best describe your organisation/institution/company in relation to the approval for the grid connection of a Power Generating Modules?

		Answers	Ratio
DSO		11	44.00 %
TSO		2	8.00 %
DSO/TSO trade organisation		1	4.00 %
Manufacture		7	28.00 %
Manufacture trade ordanisation		0	0.00 %
Accredited testing body (EN 17025)		0	0.00 %
Notified certification body (EN 17065)		3	12.00 %
Project developer (incl. owner)		1	4.00 %
National standard committees (CENELEC)		0	0.00 %

Figure 3 Received answers by organisation category

The submissions were divided between Member States, type of organisation and generator types (A, B, C and D) as shown below.

Table 7 Received answers by country and generator type

	Type A	Type B	Type C	Type D
Austria				
Belgium	DSO/TSO org.	DSO/TSO org. Manufacturer	Manufacturer	
Bulgaria				
Croatia				
Cyprus				
Czechia				
Denmark	DSO Manufacturer		DSO	Developer
Estonia				
Finland				

France				
Germany	Manufacturer	Manufacturer	Manufacturer	Manufacturer
Greece				
Hungary				
Ireland				
Italy	DSO	DSO	DSO	
Latvia				
Lithuania				
Luxembourg				
Malta				
Netherlands	DSO		Notified cert. body	
Poland			Notified cert. body	Manufacture
Portugal				
Romania				TSO
Slovak Republic				
Slovenia				
Spain	DSO	DSO	DSO Notified cert. body	DSO TSO
Sweden				
Northern Ireland				
GB	DSO	DSO Manufacturer	DSO Manufacturer	DSO

The full analysis of the survey responses can be found in Annex I.

3.5 Conclusion of analysis

The overall goal of this survey was to collect information on national implementation of certification within the NC RfG, and then look for similarities and best practices.

1. Unfortunately, the differences between each implementation appear to be at such a fundamental level, that it has proved very difficult to find similarities that could be used meaningfully in the further work of this subgroup.
2. There are different uses for otherwise key concepts, notably such as PGM and SPGM. The different uses of the concepts become a challenge when doing the analysis.
3. The analysis of the survey answers did not bring about any hint to consensus of certification.
4. The survey answers did not give hint to any best practice of certification.

5. It's difficult to find the correct TSO representative or other responsible person for this area. Similarly, it will also be difficult for a manufacturer to find the valid information, especially without presence within the member state. This is a barrier to the internal market for generators.
6. It appears that in some countries, certifications from other countries are accepted. However, the process of acceptance is still national.
7. It has been discussed within the EG, if the most developed certification systems could be used as best practice. But it appears that those systems are built around national (traditional) institutions, where similar institutions are not necessarily present in other Member States.
8. While similarities are not many, the gathered information could also be used to get deeper understanding of each implementation of certification system - independently. However, diving into details of each certification systems does not bring about knowledge that is useful for the further work of this subgroup, and therefore, such analysis was not performed by this subgroup.
9. Whilst a common consensus approach to certification and compliance has not been identified across member states, the need for the work of the Expert Group and adoption of its recommendations is reinforced as the issue of each member state having its own individual process and approach without any level of harmonization is clearly evident from the survey results.

4 Family definition for PGU certificates

4.1 Introduction

According to Regulation 2016/631 (NC RfG), equipment certificates (EqCs) can be used to show compliance of a unit against the requirements found in a grid code. Obtaining an equipment certificate from an accredited certification body to demonstrate that a PGU is compliant is an expensive and time-consuming process for a manufacturer which involves testing and simulations. PGU certificates can be used as part of the compliance documentation needed to demonstrate compliance at the PoC, which can include additional simulations or on-site testing.

PGU manufacturers produce similar products with variations on power size and voltage, while keeping all other characteristics the same. It is impractical for those manufacturers to obtain individual equipment certificates for each unit – in many cases this may require testing a large quantity of units (hundreds of tests). Therefore, an approach to allow testing a representative unit of a product "family" and apply the results to other members within the family is required.

The objective of this section is to provide general family definitions based on main technology (synchronous, PPM-Wind and PPM-Inverter based) as well as a common understanding among member states on how it can be used to extent the results of tests and validated models within the range of products defined.

4.2 Purpose of the Subgroup

4.2.1 Terms of Reference

According to the terms of reference (ToR) [1], the following objective will be covered:

"Define a common product family definition and grouping criteria for an equipment certificate"

This section will provide proposals for family definition based on technology and a grouping recommendation based on how different countries approach the issue.

4.2.2 Deliverables

The applicable deliverables from [1] are as follows:

"Recommendation on testing scope and family grouping definition (including definition and usage of validated models)"

This section will provide family definition proposals as well as general recommendations on how to use the definition for transferability among members of the family based on testing or simulations.

4.3 Family Definition

4.3.1 Difficulties and Advantages

The use of family definition would bring the following advantages:

- Reduce requests for critical test permissions to grid operators, that are often not permitted.
- Faster connection as certification can be provided during initial stages of grid connection procedure.
- Having a strong validated model that provides more assurance of its accuracy; this can be done by
    - testing and validating the model against multiple controller settings of the same machine (used to investigate the influence of key settings on PGU performance), or
    - against multiple measurements from different units of the family.

A set of common difficulties are found:

- There is no common understanding of Family at EU level

- There is confusion between different certification types, eg. PGU certificate and PGM certificate.
- The Family concept can be different for SPGUs and PGUs belonging to a PPM.
- The link from PGU testing to PGM compliance monitoring is not clearly defined in many countries.
- Family definition is only suitable for PGU certification.
- The power range is used by some member states to define the scope of the family; these ranges are not harmonized and may not be sufficient to define the family scope.
- Grid operators may find it difficult to accept due to lack of understanding of the principles behind the concept.

The definition would cover all units produced by a same manufacturer that share key characteristics like main driving technology and controller hardware and software (all relevant controllers influencing the electrical characteristics) and share a common simulation model (when applicable).

4.3.2 Existing Approaches

When looking into the different available codes and standards accepted and created by member states, the following were identified as having "family" definitions:

- Italy: CEI-016:2022 in Nter 1 and N.1.2 and CEI 0-21:2022 in B.1.6.4
- UK: G99 engineering recommendations amendment 9 in section 15.6
- Germany: TR8 (Rev 9) in section 2.12.2 (general provisions on transferability of test reports) and annex D.1 (extended transfer options for components of a combustion power engine) of and D.2.3 (power transfer limit rule)
- Spain: Technical standard for monitoring the compliance of power generating modules according to EU Regulation 2016/631 in section 4.5
- ISO8528-6 (Draft standard) in section 3.1.49
- EN50549-10:2022 section 5.13.1
- IEC 61400-21-1:2019, Annex F

4.3.3 Common Points among Approaches

The following table will include a summary of the main aspects obtained from the analysed documents and standards:

Table 8 SPGU Common Product Family Definition Characteristics

Document	Section	Concept	Main Components	Power Range
IT (CEI 016/021)	Nter 1	where the whole generator (generator and engine sub system) with same technology, number of phases, that is differentiated by voltage, current and power and share the same voltage and excitation system, generator control system and	Alternator AVR Engine Engine governor/ control system Other controller for	Root of 10 Rule / tests on smallest and biggest family elements

		with transducers sized to different power size	reactive power control Auxiliary systems	
DE	VDE 4110/4120 concept	Power ranges-based concept	Synchronous generator Voltage regulator Combustion engine type power/speed controller Auxiliary units	1) from 1/sqrt(10)to sqrt(10) factor of tested Genset's rated apparent power. 2) tests on smallest and biggest family elements
DE	TR8 Type 1, Annex D. Title : Transfer of test reports for Type 1 Ces	Provision of TR8 should be applicable only in the absence of specification in the grid code. Transferring the results in whole or part is allowed for the following cases: a- Combustion engine type: Cross technology transfer is not permitted (ed gas engine to diesel engine...) b- Auxiliary units : FRT should be separately verified if auxiliary unit is different. And the auxiliary unit should be included in certificate c- Voltage regulator : Transfer of FRT is allowable for regulators of the same type or those completely compatible in terms of control structure and operated in the same operating mode. Deviating control parameter setting is allowed. d- Power/Speed controller: these have to be considered for the transfer of the FRT test if these react within the FRT boundary curve of the grid code. e- Synchronous generator : Transfer of test where different generator (manufacturer) are used must be examined for allowability. If a different excitation system is used, its equivalence must be demonstrated. For the case of different PGU version with same power, it is the	a- Combustion engine type b- Auxiliary units c-Voltage regulator d- Power/Speed controller e- Synchronous generator	Power range from 1/sqrt(10) to sqrt(10)

		manufacturers responsibility to demonstrate that the most unfavorable conditions has been tested in agreement with the certifier		
ES	NTS, section 4.5	Equipment certificates of a PGU may be used for other PGUs of similar characteristics, without the need for retesting. In such cases, the original equipment certificates shall be referred to as "type-per-requirement PGU certificates" 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 approved certifier shall perform the evaluation:	Alternator Voltage controller including PSS Prime mover power/speed controller	PGU transfer within +/-25% of nominal power certified unit shall be permitted
ISO (8528-6 DRAFT)		group of generating sets with the similar behaviour, same technology and has same structure of components, but with different rated output and/or different voltage levels.	A generating set model can consist of the following functional blocks: • Engine and Engine controller/governor • A.C. generator • Excitation machine • Excitation controller/Automatic voltage regulator (AVR) • Generating set controller (if applicable) • Protective devices (if available) • Measurement transformers (if applicable)	
EN (50-549-10 DRAFT)	Section 5.13.1	Families are normally defined as set of generating units with same technology and similar behaviour and design but with different nominal power and/or different voltage	A generating unit can be represented by the following main components: – Synchronous machine including excitation system – Automatic Voltage Regulator (AVR)	

			– Prime Mover (main source of Energy) – Control system of the prime mover	
UK		A family approach to type testing is acceptable, whereby Generating Units that are the same model and produced by the same Manufacturer but vary in electrical output can be considered to be Type Tested once one Generating Unit in the family has been shown to be compliant	Generating Units have the same control systems	Generating unit from 1/sqrt(10) to sqrt(10) times the tested generating unit name plate rating (W)

The following table summarized the findings for PPM - Wind power-generating unit (Wind PGU) definitions:

Table 9 PPM – Wind power-generating unit (Wind PGU) Common Product Family Definition Characteristics

Document	Section	Concept	Main Components	Power Range
ES (NTS v2.1)	Section 4.5	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 authorized certifier shall carry out the assessment.	• **Electrical generator** with the same design specifications: > Nominal active power ±25% of the value corresponding to the electrical generator being tested > Same topology (e.g., asynchronous squirrel cage, doubly fed, etc.) > Same static connection voltage (asynchronous generators only) > Transformation ratio of ±20% (asynchronous generators only) • **Electric converter**(s) if any, with same hardware and specifications to support voltage dips • Percentage short-circuit voltage of the **transformer**, referring to	**Nominal active wind turbine power within ±25 %** of the value of the tested wind turbine.

			the base of the nominal active power of the wind turbine, within ±20 % of the value of the tested wind turbine (not applicable to PGUs without a transformer connected to the medium voltage circuit)	
IT (CEI 0-16:2022-03)	Annex N.1	For all types of generators it is also specified that the tests carried out on a given type of generator are considered valid in the case of variations in the configuration of the internal components, if they are equivalent with regard to the electrical characteristics towards the grid, with adequate supporting technical documentation. The identification of the internal components of the generator, relevant to the requirements that are the subject of this standard, shall be reported in the type test report issued by the laboratory.	The manufacturer shall provide an appropriate description of why the generators can be considered as belonging to the same family. In this regard, the identification of the internal components of the generator, relevant to the requirements that are the subject of this standard, shall be reported in the test report issued by the laboratory.	1) Demonstration of conformity of the **two extremes (higher / lower power)** of the systems considered implies the conformity of each unit of the family 2) Test results will be representative for similar generators with **rated active power between 1/sqrt(10) and sqrt(10)**
IEC 61400-21-1:2019	Annex F	This guideline is intended to enable the possibility to share applicable tests results across turbines from the same product platform and thereby allowing for a possible reduction of the total number of tests. The overall structure of the major component block is shown in Figure F.1. If changes to a given block is not affecting a given test listed in Table F.1, a new test is not required for this item.	• Aerodynamic: blades, pitch system, rotor • Mechanical: gearbox, drivetrain • Generator system: generator, converter • Electrical equipment: transformer, capacitor banks, filter, auxiliary supply, circuit breaker, cables • Grid protection: grid protection function • Control: control SW,	In this respect, turbines are considered to be part of a turbine product platform of the type, the main components and its control schemes are the same. Power rating inside a product platform may vary, but

		Example: a change to the aerodynamics, like a bigger rotor, does not affect the harmonics, so a new harmonic measurement is not needed, but it does influence the flicker, so this test has to be repeated. **Type testing of one turbine that is part of a product platform can be considered sufficient to cover the entire turbine product platform, provided that a documented risk assessment is carried out to determine which type tests are valid and which tests need to be repeated on the rest of the turbine product platform.** If it can be reasoned that the changes that have been implemented pose no significant risk of changing the electrical performance of the unit, then there is no need to perform new tests and measurements on the wind turbine with the changes. In these cases, the measurement and test results can be adapted to the other wind turbines within the product platform.	converter SW, pitch control, controller HW type	typically **by not more than ±25 %.**
DE (VDE-AR-N 4110/4120/ 4130)	Section 11.2.1	The measurement results obtained for the power generating unit concerned are permitted to be transferred in full or in parts to other power generating units provided that	The execution and the control technology relevant for the electrical properties including the software used in these power generating units are technically equivalent to the original.	1) Results for the minimum and maximum power variants 2) The rated apparent power of the power generating unit to be certified is for Type 2 installations between times 1/sqrt(10) and x2 the rated apparent power of the surveyed

				power generating unit.
UK		A family approach to type testing is acceptable, whereby Generating Units that are the same model and produced by the same Manufacturer but vary in electrical output can be considered to be Type Tested once one Generating Unit in the family has been shown to be compliant	Generating Units have the same control systems	Generating unit from 1/sqrt(0) to x2 generating unit name plate rating (W)

The following tables summarizes the findings for PPM inverter based PGUs (photovoltaic or other non-wind related) definitions:

Table 10 PPM - Inverter based PGU (photovoltaic or other non-wind) Common Product Family Definition Characteristics

Document	Section	Concept	Main Components	Power Range
ES	NTS2.1, applicable to TED 749/2020 (also found in UNE 217001 and UNE 217002)	Equipment certificates of a PGU may be used for other PGUs of similar characteristics, without the need for retesting. In such cases, the original equipment certificates shall be referred to as "type-per-requirement PGU certificates" 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 approved certifier shall perform the evaluation.	1. Topology - bridge - location of filters - location of relays 2. Isolation class 3. AC connection (1~ or 3~) 4. Nominal AC current between ±50% Iac from tested PGU 5. Control software or algorithm 6. Modularity is allowed	Not defined, as a current range is defined
IT	CEI-0-16:2022, N.1.2 CEI 0-21:2022, B.1.6.4	For all types of generators, it is also specified that tests performed on a given type of generator are considered valid in the case of variations in the composition of internal components, if they are equivalent for the purpose of electrical behaviour towards the grid, against adequate supporting technical documentation In this regard,	1. control electronics 2. power part (bridge) 3. number of phases. 6. Modularity is allowed (case B: modular generators, consisting of a basic element that is repeated N times in larger sizes)	Between 1/sqrt(10) and sqrt(10), so approximately between 0.32 - 3.0 p.u.

		the identification of the internal components of the generator, relevant to the requirements that are the subject of this standard, shall be reported in the report of the type test issued by the laboratory.		
DE	FGW TG8 (Rev. 9), section 2.12.2, Type 2applicable to VDE-AR-N 4110 and VDE-AR-N 4120 VDE 0124-100, applicable to VDE.AR.N 4105	A measuring campaign compliant with TG 3, Annex D, Chapter 2 to 6, performed for a PGU with any design apparent power can be transferred to PGUs in the rated apparent power range between 1/√10 and two (2) times the rated apparent power (Type 2). PGUs within this transferable range from a family. All relative results, which are relative to the design apparent power or the rated current In, or times, are transferred directly without alteration. Absolute values are transferred linearly according to the ratio of the respective design apparent power. If the certification body is plausibly presented with an argument that a deviating transfer is allowable based on documentation, the procedure specified above may be deviated from in agreement with the manufacturer. The deviation must be justified in the unit certificate. In addition, the manufacturer must technically justify to the certification body that the PGU characteristic measured during the respective tests are identical or can be transferred as described above. The justification should include all technical PGU characteristic and differences, which may influence the respective characteristics. The certification body checks the justification. Alternatively, the	The design and the control engineering critical to the electrical characteristics including the software used are equivalent from a technical perspective	1) between 1/sqrt(10) and x2 times the rated apparent power. 2) test results for the smallest and largest power version

		certification body can perform an independent assessment of transferability. The manufacturer presents the certification body, on request, the technical data or PGU description necessary to perform the test or carry out the assessment.		
UK		A family approach to type testing is acceptable, whereby Generating Units that are the same model and produced by the same Manufacturer but vary in electrical output can be considered to be Type Tested once one Generating Unit in the family has been shown to be compliant	Generating Units have the same control systems	Generating unit from 1/sqrt(10) to x2 generating unit name plate rating (W)

4.4 Family Definition Proposals

This section will cover the family definition proposals based on each technology type.

The manufacturer must technically justify to the certification body that the PGU characteristics measured during the respective tests are representative of, or can be transferred to, the other members of the product family. The justification shall include all technical PGU characteristics and differences, which may influence the respective behaviour. Alternatively, the certification body can perform an independent assessment of transferability.

4.4.1 SPGU

4.4.1.1 Definition Proposal

Generating units are considered in the same family if they share the following characteristics:

- Prime mover technology (gas engine, gas turbine, hydro turbine, etc)
- Control system of the prime mover (governor) brand and model with equivalent control software*
- Alternator type - Synchronous generator
- Automatic Voltage Regulator (AVR) brand and model with equivalent control software*
- Simulation model structure** (validated) when required (where FRT requirements need to be considered)

*Different versions of the control software may be accepted if there are no changes to relevant functions for grid parallel operation that may affect compliance with the requirements; this needs to be described and justified within the manufacturers declaration and will be the certifiers decision to accept or reject.

**Structure of the model cannot be modified, while the parameters of the model can be changed.

The brand (manufacturer), construction (salient pole or round rotor, pole pitch), excitation method (PMG, auxiliary winding, etc.) if technically equivalent, associated to the synchronous generator are not relevant for this definition because the active and reactive power response of the unit solely depend on the unit's prime mover controller and AVR.

The applicability range should be defined as follows:

1. Based on the tests done on one representative unit of the family and applied to a range defined by the manufacturer's declaration and in agreement with the certifier. When FRT capability needs to be considered, the unit needs to have undergone a simulation model validation process that includes testing and validating the model against the corresponding measurements. A stability check (by simulation) should be performed for multiple controller settings of the same machine (used to investigate the influence of key settings on PGU performance).

It is recommended not to limit the family grouping to a pre-defined power range because the ratings and capabilities of PGU components, such as the automatic voltage regulator, will already define a natural boundary, without imposing arbitrary limits.

If it is considered mandatory by member states to impose such arbitrary limits, then two proposals for defining a reasonable range are outlined below.

2. Based on the tests done on the smallest and biggest representative units of the family****.
3. Based on a range dependent on the tested unit's nominal active power; this can be defined as in Germany (1/root 10 to root 10), but never smaller than the range defined by Spain (±25% of the nominal active power).

**** Smaller or larger units than those tested may be included within the family range based on the justification provided within the manufacturer's declaration and it will be on the certifiers judgment to accept or reject.

4.4.1.2 Effects on main component changes

When at least one of the unit's main components (prime mover, prime mover control, alternator type, AVR) has changed, it now differs from the overall family that had been originally tested in such a way that it is not possible to classify the generating unit as a family member.

It is expected that if this occurs, the transferability of the test results associated to the shared components shall be accepted, provided that a documented risk assessment that identifies which tests are valid and which tests need to be repeated is made.

For example, a generating unit can install an automatic voltage regulator which is different from the one installed on the tested generating unit and share the rest of the components. Only the tests associated to this new component will be carried out.

The change of a component may trigger a subset of tests depending on the risk assessment performed and the impact it has on the static and dynamic behaviour of the generating unit. The following table (partly taken and translated from Italian CEI 0-16) shows the possible tests that shall be repeated depending on the main components that differ from the reference type tested generating unit.

Table 11 SPGU Component Change Testing Needed

Article	Capability / Electrical characteristic	Main Component			
NC RfG Article	**Capability / Electrical characteristic**	**Prime Mover**	**Prime mover control system**	**Alternator Type**	**AVR (excitation control)**
13(1)(a)	Frequency ranges	X		X	
13(1)(b)	Rate of Change of Frequency (RoCoF) withstand capability	X		X	
13(2)	Limited Frequency Sensitive Mode – Overfrequency (LFSM-O)		X		
14(3) 16(3)	Fault-ride-through (FRT) capability	X(*)	X(**)	X(***)	X(****)
15(2)(a)	Active power controllability		X		
15(2)(c)	Limited Frequency Sensitive Mode – Underfrequency (LFSM-U)		X		
15(2)(d)	Frequency Sensitive Mode (FSM)		X		
15(2)(e)	Frequency restoration control		X		
16(2)	Voltage ranges			X	
17(3)	Post-fault active power recovery	X	X		
18 (2)	Reactive power capability			X	X
N/A	Reactive power control modes		X(*****)	X	X
15 (6) (c)	Simulation Model	X(*)	X(**)	X(***)	X(****)
N/A	Harmonics, Interharmonics and higher frequency components			X	
N/A	Flicker during continuous operation			X	
N/A	Flicker and voltage change during switching operations			X	

X(*)	Requested if the characteristics and design of the generator are substantially different from the one originally tested e.g. the excitation system has different technology, the manufacturer adopts different criteria (e.g. different type of cooling)
X(**)	Requested if the voltage regulator has a consistent different response
X(***)	Requested if the speed control device has a different response
X(****)	Control system may be tested by means of product standards if available
X(*****)	Only if reactive logics are present in the governor control

The change of main components can also be considered applicable for existing units where a component is replaced (for example due to aging).

4.4.2 PPM – Rotating generation based PGU (non-wind)

4.4.2.1 Definition Proposal

Generating units are considered in the same family if they share the following characteristics:

- Prime mover technology (gas engine, gas turbine, hydro turbine, etc)
- Control system of the prime mover (governor) brand and model with equivalent control software*
- Alternator type – Asynchronous generator (different types)
- Simulation model structure** (validated) when required (where FRT requirements need to be considered)

*Different versions of the control software may be accepted if there are no changes to relevant functions for grid parallel operation that may affect compliance with the requirements; this needs to be described and justified within the manufacturers declaration and it will be on the certifiers judgment to accept or reject.

**Structure of the model cannot be modified, while the parameters of the model can be changed.

The applicability range should be defined as follows:

1. Based on the tests done on one representative unit of the family and applied to a range defined by the manufacturer's declaration and in agreement with the certifier. When FRT capability needs to be considered, the unit needs to have undergone a simulation model validation process that includes testing and validating the model against the corresponding measurements. A stability check (by simulation) should be performed for multiple controller settings of the same machine (used to investigate the influence of key settings on PGU performance).

It is recommended not to limit the family grouping to a pre-defined power range because the ratings and capabilities of PGU components will already define a natural boundary, without imposing arbitrary limits.

If it is considered mandatory by member states to impose such arbitrary limits, then two proposals for defining a reasonable range are outlined below.

2. Based on the tests done on the smallest and biggest representative units of the family***.
3. Based on a range dependent on the tested unit's nominal active power; this can be defined as in Germany (1/root 10 to root 10), but never smaller than the range defined by Spain (±25% of the nominal active power).

*** Smaller or larger units than those tested may be included within the family range based on the justification provided within the manufacturer's declaration and it will be on the certifiers judgment to accept or reject.

4.4.2.2 Effects on main component changes

When at least one of the unit's main components (prime mover, prime mover control, alternator type) has changed, it now differs from the overall family that had been originally tested in such a way that it is not possible to classify the generating unit as a family member.

It is expected that if this occurs, the transferability of the test results associated to the shared components shall be accepted, provided that a documented risk assessment that identifies which tests are valid and which tests need to be repeated is made.

For example, a generating unit can install a new type of generator (different type of asynchronous, from wound rotor to slip ring generator) which is different from the one installed on the tested generating unit and share the rest of the components. Only the tests associated to this new component will be carried out.

The change of a component may trigger a subset of tests depending on the risk assessment performed and the impact it has on the static and dynamic behaviour of the generating unit. The following table shows the possible tests that shall be repeated depending on the main components that differ from the reference type tested generating unit.

Table 12 PPM – Rotating generator based PGU Component Change Testing Needed

Article	Capability / Electrical characteristic	Main Component		
NC RfG Article	**Capability / Electrical characteristic**	**Prime Mover**	**Prime mover control system**	**Alternator Type**
13(1)(a)	Frequency ranges	X		X
13(1)(b)	Rate of Change of Frequency (RoCoF) withstand capability	X		X
13(2)	Limited Frequency Sensitive Mode – Overfrequency (LFSM-O)		X	
14(3) 16(3)	Fault-ride-through (FRT) capability	X(*)	X(**)	X(***)
15(2)(a)	Active power controllability		X	
15(2)(c)	Limited Frequency Sensitive Mode – Underfrequency (LFSM-U)		X	
15(2)(d)	Frequency Sensitive Mode (FSM)		X	
15(2)(e)	Frequency restoration control		X	
16(2)	Voltage ranges			X
17(3)	Post-fault active power recovery	X	X	
18 (2)	Reactive power capability			X
15 (6) (c)	Simulation Model	X(*)	X(**)	X(***)
N/A	Harmonics, Interharmonics and higher frequency components			X
N/A	Flicker during continuous operation			X
N/A	Flicker and voltage change during switching operations			X

X(*)	Requested if the characteristics and design of the generator are substantially different from the one originally tested e.g. the excitation system has different technology, the manufacturer adopts different criteria (e.g. different type of cooling)
X(**)	Requested if the voltage regulator has a consistent different response
X(***)	Requested if the speed control device has a different response

The change of main components can also be considered applicable for existing units where a component is replaced (for example due to aging).

4.4.3 PPM – Wind power-generating unit (Wind PGU)

4.4.3.1 Definition Proposal

Power-generating units are considered in the same family (product platform) if they share the following characteristics:

- Equivalent design and control engineering critical to the electrical characteristics*
- Equivalent unit controller software**
- Same model structure*** (validated) when required

*Refer to Table 13

** Different versions of the control software may be accepted if there are no changes to relevant functions for grid parallel operation that may affect compliance with the requirements; this needs to be described and justified within the manufacturers declaration and it will be on the certifiers judgment to accept or reject.

***Structure of the model cannot be modified, while the parameters of the model can be changed.

The applicability range should be defined as follows:

1. Based on the tests done on one representative unit of the family and applied to a range defined by the manufacturer's declaration and in agreement with the certifier. When FRT capability needs to be considered, the unit needs to have undergone a simulation model validation process that includes testing and validating the model against the corresponding measurements. A stability check (by simulation) should be performed for multiple controller settings of the same machine (used to investigate the influence of key settings on PGU performance).

It is recommended not to limit the family grouping to a pre-defined power range because the ratings and capabilities of PGU components will already define a natural boundary, without imposing arbitrary limits.

If it is considered mandatory by member states to impose such arbitrary limits, then two proposals for defining a reasonable range are outlined below.

2. Based on the tests done on the smallest and biggest representative units of the family****.
3. Based on a range dependent on the tested unit's nominal active power; this can be defined as in Germany (1/root 10 to 2), but never smaller than the range defined by Spain (±25% of the nominal active power).

The manufacturer shall technically justify to the certification body that the PGUs electrical characteristics measured during the respective type tests are identical or can be transferred as described above. The justification shall include all technical PGU electrical characteristic and differences, which may influence the respective electrical performance. The certification body checks the justification. Alternatively, the certification body can perform an independent assessment of transferability. The manufacturer presents the certification body, on request, the technical data (e.g., electrical parameter datasheets) or PGU description necessary to perform the test or carry out the assessment.

**** Smaller or larger units than those tested may be included within the family range based on the justification provided within the manufacturer's declaration and it will be on the certifiers judgment to accept or reject.

4.4.3.2 Effects on main component changes

When at least one of the main components of a wind power-generating unit (e.g., blades, gearbox) has changed from the power-generating unit that has been originally tested, transferability of the test results associated to the shared components shall be accepted, provided that a documented plausibility check and risk assessment that identifies which tests are valid and which tests need to be repeated is made.

The risk assessment can be different depending on the Wind PGU type. The wind industry distinguishes between the following:

- Type 1: Asynchronous generators directly connected to the grid
- Type 2: Variable rotor resistance asynchronous generator
- Type 3: Doubly fed asynchronous generator
- Type 4: Connected to the grid through a full-scale power converter

For example, a power-generating unit can have a new gearbox implemented or be equipped with different blades (e.g., increased blade length) which is different from the one implemented / equipped on the tested reference power-generating unit and share the rest of the components.

Each Wind PGU can be represented in a modular structure, where the different subsystems as well as the main components and control systems for the different subsystems are defined.

The change of a component may trigger a subset of tests depending on the risk assessment performed and the impact it has on the steady-state and dynamic behaviour of the power-generating unit. Table 13 (partly taken from IEC 61400-21-1) shows which wind power-generating unit subsystems have an influence on the measured performance as well as the possible tests that shall be repeated depending on the main components that differ from the reference type tested generating unit.

Table 13: Subsystems influencing the electrical characteristics of the Wind PGU

		Subsystem					
NC RfG Article	**Capability / Electrical characteristic**	**Aerodynamic**	**Mechanical**	**Generator system**	**Electrical equipment**	**Grid protection**	**Control**
13(1)(a)	Frequency ranges		X[4)]	X	X[3)]		
13(1)(b)	Rate of Change of Frequency (RoCoF) withstand capability			X[3)]	X	X	
13(2)	Limited Frequency Sensitive Mode – Overfrequency (LFSM-O)						X
14(3) 16(3)	Fault-ride-through (FRT) capability		X[4)]	X[1)]	X		X
15(2)(a)	Active power controllability			X[3)]			X
15(2)(c)	Limited Frequency Sensitive Mode – Underfrequency (LFSM-U)						X

15(2)(d)	Frequency Sensitive Mode (FSM)						X
15(2)(e)	Frequency restoration control						X
16(2) 25(1)	Voltage ranges		X[4)]	X	X[3)]		
21(2)	Synthetic inertia	X[5)]		X	X		X
20(3)	Post-fault active power recovery			X[1)]	X		X
20(2)(b)(c)	Fast fault current injection (FFCI)			X[1)]	X		X
21(3)(b)(c)	Reactive power capability			X	X[6)]		X
21(3)(d)	Reactive power control modes				X[6)]		X
N/A	Harmonics, Interharmonics and higher frequency components			X	X		X
N/A	Flicker during continuous operation	X[5)]	X	X	X		X
N/A	Flicker and voltage change during switching operations	X[5)]	X	X	X		X

[1)] Depending on the type of turbine, the generator also has some influence on the FRT performance.

Depending on the Wind PGU type some of the following main components will be part of the different subsystems for the different Wind PGU types (taken from IEC 61400-21-1):

Table 14: Wind PGU subsystems and main components

Subsystem	Main Component	Description
Aerodynamic	Blades	Blades of the Wind PGU
	Pitch system	Mechanical / electrical system to rotate the blades
	Hub	Fixture for attaching the blades assembly to the rotor shaft
Mechanical	Gearbox	Gearbox
	Drivetrain	Mechanical drive train
Generator system[1]	Generator	Generator of the Wind PGU[2]

[1] Terminology as per IEC TS 61400-21-4 ED1: Power conversion system.

[2] Depending on the Wind PGU type: asynchronous, synchronous, DFIG, etc.

[3] On Full-scale converter turbines only “Converter” is relevant

	Converter	Converter system for the type 3 and type 4 Wind PGU
Electrical equipment	Transformer	LV to MV transformer
	Capacitor banks	Reactive power compensation
	Filter	Filter system for switch harmonics
	Auxiliary supply	Supply of the auxiliary equipment in the Wind PGU
	Circuit breaker	Main circuit breaker of the Wind PGU
	Cables	Tower cables, etc.
Grid protection	Grid protection functions	Frequency / voltage protection, RoCoF protection
Control	Control software, converter software, pitch control, speed control, torque control, controller hardware type	Active and reactive power control of the generator system[1], active and reactive power control of the grid side system, Control system to control the pitch angle of the blades (pitch control) / the rotational speed of the blades (speed control) / the torque to the main shaft (torque control)

4.4.4 PPM - Inverter based PGU (photovoltaic, battery or other non-wind)

4.4.4.1 Definition Proposal

Generating modules are considered in the same family if they share the following characteristics:

- Equivalent control electronics and construction topology design (bridge, location of filters) and control engineering critical to the electrical characteristic
- same number of phases
- Equivalent unit controller software*
- Simulation model structure** (validated) when required (where FRT requirements with fast reactive current injection need to be considered)

* Different versions of the control software may be accepted if there are no changes to relevant functions for grid parallel operation that may affect compliance with the requirements; this needs to be described and justified within the manufacturers declaration and it will be on the certifiers judgment to accept or reject.

**Structure of the model cannot be modified, while the parameters of the model can be changed.

The applicability range should be defined as follows:

1. Based on the tests done on one representative unit of the family and applied to a range defined by the manufacturer's declaration and in agreement with the certifier. When FRT capability needs to be considered, the unit needs to have undergone a simulation model validation process that includes testing and validating the model against the corresponding measurements. A stability check (by

[4] Only relevant for Type 3 WTGs (DFIG)

[5] testing the biggest rotor shall cover all the smaller rotor sizes and a variation of 10% on rotor length is neglectable so this shall be included on the same family definition

[6] Only required for Capacitor banks if any are required. Transformer is a well-known passive component that can be simulated if required

simulation) should be performed for multiple controller settings of the same machine (used to investigate the influence of key settings on PGU performance).

It is recommended not to limit the family grouping to a pre-defined power range because the ratings and capabilities of PGU components will already define a natural boundary, without imposing arbitrary limits.

If it is considered mandatory by member states to impose such arbitrary limits, then two proposals for defining a reasonable range are outlined below.

2. Based on the tests done on the smallest and biggest representative units of the family***.
3. Based on a range dependent on the tested unit's nominal active power; this can be defined as in Germany (Pgen/√10 < Pgentestate < Pgen x 2), but never smaller than the range defined by Spain (±50% of the nominal alternating current).

*** Smaller or larger units than those tested may be included within the family range based on the justification provided within the manufacturer's declaration and it will be on the certifiers judgment to accept or reject.

For Modular generators, consisting of a basic element that is repeated N times used to form larger generating units, at least one complete test session is foreseen on the smaller size generator and the confirmation of the correct settings on the other models of the assembly by carrying out a partial test session on the higher power model regarding the reactive power capability and the active power response in case of frequency changes. The voltage quality requirements are fulfilled if the overall generator contribution (evaluated as the arithmetic sum of the individual generators of the lower size) is within the prescribed limits. If this is not the case, a test must be carried out on the maximum generator size

4.4.4.2 Effects on main component changes

When at least one of the main components (see table below) has changed from the power-generating unit that has been originally tested, transferability of the test results associated to the shared components shall be accepted, provided that a documented plausibility check and risk assessment that identifies which tests are valid and which tests need to be repeated is made.

For example, a generating unit can operate with different DC sources, such as, PV modules and batteries, but the performance is governed in both cases by the same control software. Only the tests associated to this new component will be carried out.

The change of a component may trigger a subset of tests depending on the risk assessment performed and the impact it has on the static and dynamic behaviour of the generating unit. The following table shows the possible tests that shall be repeated depending on the main components that differ from the reference type tested generating unit.

Table 15 Subsystems influencing the electrical characteristics of the PPM – inverter based PGU (non Wind)

		Subsystem		
NC RfG Article	**Capability / Electrical characteristic**	**Electrical equipment**	**Grid protection**	**Control**
13(1)(b)	Rate of Change of Frequency (RoCoF) withstand capability		X	
13(2)	Limited Frequency Sensitive Mode – Overfrequency (LFSM-O)			X
14(3) 16(3)	Fault-ride-through (FRT) capability	X		X

15(2)(a)	Active power controllability			X
15(2)(c)	Limited Frequency Sensitive Mode –Underfrequency (LFSM-U)			X
15(2)(d)	Frequency Sensitive Mode (FSM)			X
15(2)(e)	Frequency restoration control			X
21(2)	Synthetic inertia			X
20(3)	Post-fault active power recovery	X		X
20(2)(b)(c)	Fast fault current injection (FFCI)	X		X
21(3)(b)(c)	Reactive power capability	X		X
21(3)(d)	Reactive power control modes			X
N/A	Harmonics, Interharmonics and higher frequency components	X		X
N/A	Flicker during continuous operation	X		X
N/A	Flicker and voltage change during switching operations	X		X
N/A	Voltage and frequency protection		X	
N7A	DC injection	X		X

Table 16: PPM – inverter based PGU (non Wind) subsystems and main components

Subsystem	Main Component	Description
Electrical equipment	Filter	Filter system for switch harmonics
	Transformer	Ratings (apparent power, voltage), vector groups, and grounding are as defined by the manufacturer
	Circuit breaker / disconnection relays	Main disconnection means of the PPM
	Topology	Bridge type and components
	DC source	Generally, PV but also batteries or other technologies can be connected to the DC input of the PPM
Grid protection	Grid protection functions	Frequency / voltage protection, RoCoF protection
Control	Control software, converter software	Active and reactive power control of the generator system or active and reactive power control of the grid side system which can be the same at unit level

4.5 Transferability and Testing Scope within the Family

This section provides recommendations on how the family definition could be applied based on the following type of requirements:

- Active power controllability and control range
- Reactive power capability and control modes

- Dynamic behaviour capability
- Other capabilities
- Capabilities under investigation

In general, requirements that are purely dependent on the behaviour of the unit controller(s) can be proven for all members of the family based on the test results of the selected representative unit(s); those requirements defining the dynamic behaviour of the PGU which dependent on physical or constructive attributes can be proven for all members of the family based on simulations performed with the validated model from the selected (and tested) representative unit(s). Finally, those requirements that may be impacted by the construction differences of the PGU will be considered as capabilities under investigation and should be checked on site along with any additional compliance testing pending at plant level. The following are evidence support documents recommended:

- Manufacturer's declaration
- Testing report
- Simulation model and simulation analysis
- Data sheets
- Power Generating Unit Component certificate*

*Additional testing with the new PGU component (part of the PGU) is required to show the overall behaviour or performance of the PGU

4.5.1 Active Power Controllability and Control Range

These requirements are related to the active power behaviour and are mainly dependent on the unit controllers.

The following requirements are under consideration:

Table 17: Active Power Controllability and Control Range Requirements

NC RfG, Article	SPGM / PPM	Capability
13(1)(b)	SPGM, PPM	Rate of Change of Frequency (RoCoF) withstand capability
13(2)	SPGM, PPM	Limited Frequency Sensitive Mode – Overfrequency (LFSM-O)
13(6), 14(2)	SPGM, PPM	Remote cessation of active power (Logic interface 1 & 2)
14(2), 15(2)(a)	SPGM, PPM	Active power controllability
15(2)(c)	SPGM, PPM	Limited Frequency Sensitive Mode –Underfrequency (LFSM-U)
15(2)(d)	SPGM, PPM	Frequency Sensitive Mode (FSM)
15(2)(e)	SPGM, PPM	Frequency restoration control[3]
15(6)(e)	SPGM, PPM	Rates of change of active power output (ramping limits)
21(2)	PPM	Synthetic inertia[3]
19(2)	SPGM	Power system stabilizer (PSS)
21(3)(f)	PPM	Power oscillation damping (POD) control[3,4]

[3] This is a non-mandatory requirement in the NC RfG.

[4] Active power-based power oscillation damping (POD-P).

Regarding the supporting evidence, the use of a testing reports performed by an authorized laboratory or body and a manufacturers declaration explaining how the different members of the family can be covered by those tests are required. This information would then be used by the certifier to provide a final statement for the whole family.

Note: Capabilities can also be implemented in PGS component (e.g., Power Plant Controller (PPC)).

4.5.2 Reactive Power Capability and Control Modes

These requirements are related to the reactive power behaviour and are mainly dependent on the unit controllers, as well as reactive power capability of the PGUs (which should be equivalent throughout the family).

The following requirements are under consideration:

Table 18: Reactive Power Capability and Control Modes Requirements

NC RfG, Article	SPGM / PPM	Capability
18(2)(b), 21(3)(b)	SPGM, PPM	Reactive power capability at maximum capacity
18(2)(c), 21(3)(c)	SPGM, PPM	Reactive power capability below maximum capacity
21(3)(d)	PPM	Reactive power control modes
21(3)(f)	PPM	Power oscillation damping (POD)[3,5]
N/A	SPGM, PPM	Reactive power Dynamic behaviour (e.g. ramp rates)

Regarding the supporting evidence, the use of a testing report performed by an authorized laboratory or body and a manufacturers declaration explaining how the different members of the family can be covered by those tests are required. This information would then be used by the certifier to provide a final statement for the whole family.

Note: Capabilities can also be implemented in PGS component (e.g., Power Plant Controller (PPC)).

4.5.3 Dynamic Behaviour Capabilities

These are requirements applicable during fast occurring events that are dependent on physical (inertia, …, etc.) and construction characteristics (reactances, time constants, etc.); tests or simulations shall be used to prove the capability of each family member (these simulations include any plausibility analysis necessary to consider variability of parameters provided by component manufacturers).

The following requirements are under consideration:

Table 19: Dynamic Behaviour Capabilities

NC RfG, Article	SPGM / PPM	Capability
14(3), 16(3)	SPGM, PPM	Fault-ride-through capability (UVRT, OVRT, Consecutive faults / Multiple FRT)
17(3), 20(3)	SPGM, PPM	Post-fault active power recovery
20(2)(b)	PPM	Fast fault current injection (FFCI)

Regarding the supporting evidence, the use of a testing report performed by an authorized laboratory or body shall be used to validate the model using existing standards; these models will be used to check via simulations the dynamic capability **of each family member** according to a procedure agreed with the certifier. Additionally,

[5] Reactive power-based power oscillation damping (POD-Q).

a manufacturers declaration explaining how the different members of the family can be covered by those tests will also be required. This information would then be used by the certifier to provide a final statement for the whole family.

These capabilities can be transferred without additional tests or simulations to other family members when the manufacturers declaration explanation can justify it to the certifier (e.g. in case of inverter-based PPMs, this can be done when the power electronics topology and software are equal, in which case a simulation model would not be necessary and thus is not required); The certifier may require additional documentation to provide the final capability statement.

4.5.4 Other Capabilities

These are requirements mentioned within the NC RfG that are mainly dependent on the unit controllers and the capability of the PGU or are dependent on additional components (like the protection relay):

Table 20: Other Capabilities

NC RfG, Article	SPGM / PPM	Capability
13(1)	SPGM, PPM	Frequency ranges
13(4)	SPGM, PPM	Admissible active power reduction from maximum output with falling frequency
13(7)	SPGM, PPM	Automatic connection
14(4)	SPGM, PPM	Reconnection after incidental disconnection
14(5)(b)	SPGM, PPM	Electrical protection schemes and settings
15(5)(c)	SPGM, PPM	Quick re-synchronization capability
15(6)(e)	SPGM, PPM	Active power ramping limits
16(2), 25(1)	SPGM, PPM	Voltage ranges
16(4)	SPGM, PPM	Synchronization
N/A	SPGM, PPM	Loading conditions (active power ramp rate) during synchronization
N/A	SPGM, PPM	DC injection / DC content
N/A	SPGM, PPM	Flicker during continuous operation
N/A	SPGM, PPM	Flicker and voltage change during switching operations

Regarding the supporting evidence, the use of a testing report performed by an authorized laboratory or body and a manufacturers declaration explaining how the different members of the family can be covered by those tests are required. This information would then be used by the certifier to provide a final statement for the whole family.

4.5.5 Capabilities Under Investigation

These are requirements that are dependent on specific construction characteristics (pitch winding, etc), which may vary within members of a family and could have considerable effects on unit behaviour.

Table 21: Capabilities Under Investigation

NC RfG, Article	SPGM / PPM	Capability
N/A	SPGM, PPM	Harmonics, Inter-harmonics and higher frequency components
N/A	PPM	Voltage unbalance

N/A	SPGM, PPM	Voltage phase jump angle withstand capability
N/A	SPGM	Voltage fluctuations
15(5)(a)	SPGM, PPM	Black start capability
15(5)(b)	SPGM, PPM	Capability to take part in island operation

These requirements can be included within the family transferability list based on member state specific definitions and requirements.

Regarding the supporting evidence, the use of a testing report performed by an authorized laboratory or body and a manufacturers declaration explaining how the different members of the family can be covered by those tests are required. This information would then be used by the certifier to provide a final statement for the whole family.

5 Simulation Model for dynamic verification

5.1 Introduction

The use of simulation models to verify FRT requirements is a well-used procedure in several member states; however, no standard approach for obtaining a validated model is available at EU level.

Once a model has been properly validated and the confidence level is high, it can be used to verify the capability of a unit at a specific site without additional testing; this validated model can also be used to verify the capability of other family members when a family certificate is created.

Topics like software types used, transferability of FRT capability, model validity and maintenance as well as the use of encrypted and black box models are considered within this section.

5.2 Objectives covered

5.2.1 Terms of Reference and deliverables

According to the terms of reference (ToR) [1], the following objective will be covered:

"Provide a path for a harmonized European approach to accept validated simulation models and define their recommended scope of use to substitute equipment testing"

The content will be informative and provide general information and eventual recommendations for amendment to RfG applicable articles.

This section will provide proposals for family definition based on technology and a grouping recommendation based on how different countries approach the issue. articles.

5.3 Model definition

It is understood that models that represent the generating unit can be used in the compliance verification process. The basic idea is that the static and dynamic behaviour of a generating unit can be represented with a reasonable accuracy using a simulation software, allowing the verification of the compliance conditions.

A model is basically a simplified representation of a generating unit. Generating unit models are traditionally used for different types of electrical studies like short circuit studies, load flow studies, etc; these studies are used as the basis of the design of the electrical system. The present document aims to investigate the use of models in simulation software to prove specific grid code compliance requirements with a special focus on Fault Ride Through capabilities.

5.3.1 Overview

It is not easy to give a general definition of a model. A model is an information set that can be different depending on the technology of the generating unit to be represented, the level of fidelity that is requested and the phenomena that shall be investigated.

The model normally includes:

- a representation/structure of the main components that have an influence on the electrical behaviour of a generating unit;
- model parameters, associated to physical information
- model settings, which configurable information that represents the generating unit in detail

The model representations can be based on libraries or defined by manufacturers. Model libraries are normally available for generating unit main components and they are based on models developed previously by manufacturers.

There are several model libraries and standards that include model representation for different components of generating units, but also for electrical system components (e.g. IEEE 421, IEC, etc.)

The models representations/structures available in libraries and standards do not include Grid Code logics associated to active power and reactive power control or other functionalities. Library models are simplified ones and do not necessarily reflect with a proper fidelity the behaviour of the unit. It is expected that the manufacturer of the generating unit defines the structure of the model to such a detail that it meets the level of fidelity requested to prove the corresponding capability.

The models are expected to include technology specific information. The information is associated to the components of the PGU. An example of the information that a model shall represent is described in German guideline FGW TR4, in European standard EN 50549-10:2022, component model requirement is at the moment limited to generating units connected through synchronous generator), in international standards like IEC 61400-27-1 on generic electrical simulation models or the IEEE 421.5 for excitation system models for power system stability studies.

5.3.2 Models used in compliance processes

Models used in compliance processes are expected to be validated. A validated model is capable of emulating the behaviour of a generating unit considering specific qualitative and/or quantitative criteria. A dedicated chapter of this document will deal with this point.

A validated model is frequently associated to a specific software. Validated models used in compliance verification processes include some extended information, like:

1. PGU/PGM parameters are identified within the given tolerance ranges.
2. PGU/PGM settings are mapped in simulation model and eventual applicable ranges are defined
3. Applicable simulation software is defined with eventual applicable revision and
4. Settings shall be properly configured

In addition to the PGU model, the electrical system shall be properly represented as well, using library models which are normally integrated within the selected software. The electrical system shall represent the plant conditions, or the type test conditions; The test event shall be defined in the simulation software and shall be in line with the representation of the tests carried out (eg FRT requirements for generating unit in specific conditions).

Depending on the type of simulation that needs to be performed or requirements that need to be proved, there could be the need of using RMS or EMT models. It has been recognized in various standards and guidelines that deal with modelling and requirement verification through simulations, that for the compliance verification associated to Grid Code requirements and FRT requirements, RMS models are considered acceptable; for inverter-based technology EMT models can be required on weak grid with high RES penetration.

5.4 Parameters and settings

The Power Generating Unit and Power Generating Module parameters and settings are among the most important information associated to models. Electrical System parameters and settings are also essential for the verification of the generating unit capabilities to deal with a grid event. Parameter and settings are frequently confused; therefore, it has been considered of help to provide a definition within this report.

5.4.1 PGU/PGM Model parameters

PGU/PGM parameters can be considered physical quantities associated to a generating unit or a component of the power generating unit model, such as alternator impedances and time constants (part of a PGU), line length and associated impedance (part of the PGM).

PGU/PGM parameters are frequently defined in IEC or ISO product standards. For example, alternator parameters are defined according to IEC 60034 series. The parameter measurement methods and conditions are as well described in these standards.

Permitted tolerance for most parameters are also indicated in the product standard, however manufacturers may declare better parameter tolerance ranges due to either production accuracy, material reliability, measurement accuracy, or testing/modelling results. The parameter tolerance can be indicative of product quality for specific components. It is expected that the model parameters and associated/accepted tolerance are described by the manufacturer (of the generating unit or of the component). The model shall be validated taking in consideration the corresponding tolerance and include them in the model documentation.

Component parameters and associated tolerances can have a direct impact on the capability and performance of the generating unit or module (and corresponding level of fidelity of the model).

An example of typical alternator parameters are as follows:

Table 22 Typical alternator parameters

Parameter	Unit	Definition	Standard
Sn	MVA	Rated apparent power	IEC60034
J	kgm^2	Moment of Inertia	ISO 8528-6 (IC Engines product std)
Xd	p.u.	Synchronous reactance, d-axis (unsat)	IEC 60034
Xq	p.u.	Synchronous reactance, q-axis (unsat)	IEC 60034
Xd’	p.u.	Transient reactance, d-axis (unsat)	IEC 60034
Xd“	p.u.	Subtransient reactance, d-axis (unsat)	IEC 60034
Xq“	p.u.	Subtransient reactance, q-axis (unsat)	IEC 60034
Xl	p.u.	Stator leakage reactance	IEC 60034
Td’	S	Transient time constant, d-axis (short circuit)	IEC 60034
Td“	S	Subtransient time constant, d-axis (short circuit)	IEC 60034
Tq“	S	Subtransient time constant, q-axis (short circuit)	IEC 60034
X0	p.u.	Zero sequence reactance	IEC 60034
R0	p.u.	Zero sequence resistance	IEC 60034

Note: Typically, saturated values of Xd'' and Xq'' are used to get conservative (higher fault current) results

An example of typical power transformer parameters are:

Table 23 Typical transformer parameters

Parameter	Unit	Definition	Standard
Sn	MVA	Rated apparent power	IEC 60076
Ratio	-	Basic HV/LV ratio	IEC 60076

Vector group	-	Transformer vector group Y-D	IEC 60076
Zcc%	p.u.	Short circuit voltage	IEC 60076
Copper loss	p.u.	Copper loss	IEC 60076

5.4.2 PGU/PGM Settings

PGU/PGM settings are quantities that still define the behaviour of the unit and that can be (but not necessarily are) modified.

Settings can be "inner settings" and "configurable settings".

"Inner settings" are values and variables that are in the core control, which are not expected to be modified during the lifecycle of the generating unit (modification of such settings can lead to unstable, incorrect or unpredictable behaviour of the generating unit and are not permitted by the manufacturer), or other settings which are expected to have no impact on the behaviour of the generating unit. These "inner settings" are not represented in the generating unit/module model if they have no impact on the generating unit behaviour, while other "inner settings" are frequently neglected or present using other representative variables in the power generating unit model or component.

"Configurable settings" are those that may be modified during commissioning or system fine tuning. PGU/PGM settings are normally available via HMI or embedded in the control logic (accessibility may be limited for certification).

Settings are often manufacturer specific unless explicitly defined in certain requirements (like droop value settings) and not defined in international standards.

Model configurable settings are frequently associated to a range of values as declared by the manufacturer. They are in some cases restricted by PGU/PGM physical limits.

An example of typical transformer settings are:

Table 24 Typical transformer settings

Settings	Unit	Definition	Availability
Tap-changer	-	Tap changer position	Physical / Controller

An example of typical protection settings are:

Table 25 Typical protection settings

Settings	Unit	Definition	Availability
Voltage protections	p.u.	Various level voltage protections	HMI
Current protections	p.u.	Various level current protections	HMI
Frequency protections	p.u.	Various level frequency protections	HMI

5.4.3 Electrical System parameters

Electrical system parameters are also relevant. These parameters are associated to the representation of a "typical" grid (grid topography) and they are needed for simulation studies.

The electrical system can be different in many ways and different representations can be chosen as best fit for specific simulation scenarios. Their representation is also dependent on what a specific software may permit. A typical grid representation includes as main parameters the short circuit power and the X/R impedance ratio. In general, they can be represented by a Thevenin circuit.

The electrical system parameters are representing physical characteristics. When it comes to simulation studies, these parameters can also be “variable” (which is not the case for PGU and PGM parameters). Varying electrical system parameter could provide evidence of the limit capabilities of a PGU/PGM (plausibility check).

5.4.4 Simulation Software Settings

Simulation software settings do not belong to PGU/PGM characteristic but are essential for reliable simulation results. The settings are software specific.

An example of typical simulation software settings are:

Table 26 Typical simulation software settings

Settings	Unit	Definition	Availability
RMS/EMT	-	Simulation iteration type	Simulation software
Step size	ms	Simulation iteration step size	Simulation software

5.5 Model validation process

Model validation process has been partly already described in EG ISSM report. This chapter includes extracts from the final report and provide some cross-references to standards and best practice.

Prior to going into details about methodologies and the validation process, a common understanding of model verification and validation needs to be established.

- Validation is the process of determining the degree to which a simulation model and its associated data are an accurate representation of the real world from the perspective of the intended uses of the model.
- Verification is the process of determining that a model implementation and its associated data accurately represent the conceptual description and specifications.
- Accepted Models: Models provided with the description of what the model or simulation will represent, the assumptions limiting those representations, and other capabilities needed to satisfy the user's requirements. They could also be certified models, but this is not a prerequisite.
- Certification: The official certification that a model, simulation, or federation of models and simulations and its associated data are acceptable for use for a specific purpose.

5.5.1 Validation process

In general, model validation involves some form of testing (factory and/or on-site).

Tests can be divided in two general categories:

- Tests used to validate specific logic control
- Tests used to validate natural behaviour of the generating unit which corresponds to core control and or characteristics

5.5.1.1 Tests used to validate specific logic control

These tests are frequently used with a dual purpose. A first purpose is to check that the generating unit can fulfil specific requirements in term of controllability, the second is to check that the model is able to represent the specific control with a good fidelity.

An example are the tests used to verify the Limited Frequency Sensitive Mode (LFSM) control, which are used to check the generating unit behave as expected. A generating unit model including such functionality shall replicate the unit real behaviour.

Similar tests are carried out for the different control modes associated to active power control and reactive power control.

It can happen that the specific control logics (like LFSM, Q(U), Q(P), etc.) are external control loops that provide input to the core controller of the generating unit. The tests are aimed to verify that both the “external loops” and the core control behaviour are properly represented in the model behaviour.

These tests are frequently repeated with different control settings; the model can be validated against such setting changes. However, in some cases the compliance process does not deem it as mandatory to include such control logics in the generating unit model nor to test them.

5.5.1.2 Tests used to validate the behaviour of the generating unit

These tests are used to check and validate the model of the generating unit’s main components and associated controllers. Such tests can include the definition of the Fault Ride Through capabilities of a generating unit (for very small unit FRT capabilities are not requested).

These are the approaches used in the validation process for FRT capabilities:

- “Direct approach”: Real FRT tests are carried out on the generating unit and are used to validate the model; the validated model is used to check FRT capabilities different from the ones tested;
- “Indirect approach”: Tests validating the generating unit systems and core controls (system controlling voltage/reactive power and associated values, system controlling speed/active power and associated values, additional verification necessary for the model definition such as inertia evaluation); the validated model is then used to check FRT capabilities

5.5.1.2.1 Direct approach – Real FRT tests

These tests can be carried out either in laboratories that allow the change of the voltage at the generating unit terminals according to a specific profile, or parallel to the grid where a test field container is used to create a voltage dip at generator terminals. Laboratories and test field container have limitations typically associated to the maximum power/current they allow during the tests. Field test container can create disruptions on the grid which are not always permitted by system operators.

Typically, the test involves the repetition of voltage dips with different voltage profiles.

The model validation is carried out by representing the test condition in a simulation software including the generating unit model parametrized as the tested unit. The simulation result and the real measurements taken during the test are then compared.

This type of verification is used in many countries in Europe, for example it is part of the type certification process in Germany and Spain, among others. Normally the reference standard in use is the IEC 61400-27-1 and in 61400-21, where for example in Germany, the same approach had been transposed for the other technologies in the FGW standards. The direct test approach is also used in the IEEE 1547.1 and UL 1741 in the USA.

5.5.1.2.2 Indirect approach – Test to validate generating unit system

This approach considers validating the model of the generating unit system and its corresponding general behaviour.

This approach consists of multiple tests that validate the different systems of the generating unit. In the case of a synchronous generating unit, the systems associated are the control of the reactive power (AVR control including parameters and limiter, generator, etc.), active power control (governor control and prime mover models), inertia value.

The validation is performed by comparing real tests and model simulations where test conditions are replicated in a simulation environment. The real tests can be performed using Hardware-in-the-loop test configuration for specific technology and where permitted.

Once the different system models are validated within the generating unit model, then the validated model is used to validate FRT capabilities.

The FRT capabilities are verified by reproducing test conditions as described in the “direct approach”; the simulations are considered passed if the generating unit behaviour is stable and the synchronism isn’t lost.

This approach is foreseen in some countries in Europe, for example in Germany for big generating units (limited to synchronous generators) in Spain, in Italy among others; the same approach is used in Australia and in the USA (WECC and NERC approach referring to IEEE standards defining component models and associated procedures for testing).

5.5.2 Model Validation process – Model Fidelity

Model validation consists of the verification of steady-state operational performance, dynamic response as well as small signal response.

The model validation is carried out by comparing the measurements taken during assessment tests and the corresponding model performance. The model validation consists of verifying the expected fidelity of the unit dynamic and steady state behaviour. The fidelity of the model is evaluated using a quantitative approach or a qualitative approach or a blend of the two approaches.

A quantitative approach is defined in terms of the maximum allowed deviation between the measurements and the corresponding model behaviour.

A qualitative approach implies that the deviation between measurements and the simulated behaviour are less stringent, while the measurements and the simulation shall be reasonably similar, and deviation can be justified.

A mix of the two approaches is also used, for example in case the exception from the maximum allowed quantitative deviation can be technically justified by manufacturers.

The model validation process can be different depending on unit size, but also depending on the modularity and uniqueness of some generating units.

The acceptance of the quantitative and qualitative comparison results depends also on engineering judgement and mutual agreement of the involved parties such as manufacturers and model users, e.g. TSOs. A simple quantification does not always provide a fast and simple validation answer.

A quantitative approach is more frequent in use in Europe, while a qualitative approach is more used in USA (NERC).

5.5.3 Model Validation process – Other validation methodologies used for specific studies

Models can be purpose and technology specific, for example to investigate the fault-ride through behaviour of an HVDC system or the transient stresses on a single wind turbine component. Therefore, the models need to be validated to be suitable for the intended study context and interaction phenomena.

There are mainly three types of models:

- RMS time domain models
- EMT time domain models (real-time and non-real time)
- Frequency dependent (harmonic) impedance models

The classical validation approach using measurement data from site tests and operation is not feasible for all phenomena, project stages, fault conditions, or operating conditions. Therefore, the following alternative approaches are also applied:

- Validation with the usage of measured grid data and playback of such in the models
- Validation with real-time simulator or hardware-in the-loop simulation results
- Validation with design calculations
- Validation on component or control level (e.g. in the scope of IEC 61400-21-4 for wind energy generation systems)
- Validation with other accepted simulation models (of the same or different simulation tool)

An example for the transferability of validation results is applied for wind turbine generators: WTs have larger variations so a full validation campaign for each iteration of turbine will be costly. Many of these iterations are built upon a common electrical layout and control codes. In some cases, the only difference is the name-plate rating while in other cases the hardware may scale together with the current rating of the new turbine type. Based on this, it should be considered that a validated model of one iteration is used as a benchmark to validate the subsequent iteration provided that the manufacturer can provide reasonable justification and change log.

Provisions for the extension of validated models should also be considered within reasonable justification. For example, unbalanced earth fault testing is not allowed in many test sites due to equipment and health hazards caused by over voltages in one or several phases. Instead, models fully validated for three phase earth faults can be extended to demonstrate single phase to earth fault capabilities.

The model fidelity follows the same criteria as described in 5.5.2.

5.5.4 Extended validation with configurable settings

Extended validation can be applied when the recommended approach for family definition application range is used, as this is considered the most complete validation approach.

Typically, the validation is carried out considering the limit values associated with each configurable setting. This form of validation would imply that tests are repeated considering multiple configurable setting configurations (the range of values shall be considered in the validation process). However, this can lead to a great number of tests.

It is expected that a limited number of scenarios are considered as different cases (in a way that it shows a different behaviour even if limited) that would shorten the number of tests to be carried out. In addition to that, it is expected that only "relevant" configurable settings are considered for the analysis. For example, in the specific tests to prove FRT capabilities, configurable settings associated to LFSM or FSM logics are not expected to be relevant.

As it is not always possible to define such scenarios, simulations may be repeated considering changes to each configurable parameter range as defined by the manufacturer.

This validation strategy would enable the manufacturer to guarantee the applicability of the model by testing only one representative family member, as it takes into account all relevant configurable settings and therefore possible ranges that could affect the model behaviour.

5.5.5 Model validity limits

The model developer shall mention the model's validity limits in the model documentation. Validity limits can be for example:

- Limitations for weak grid conditions: under some conditions like weak grid conditions, the validation procedure may require an additional monitoring of internal control loops. The stability of all relevant control loops must be monitored during the validation process.
- Limitations in frequency ranges: the manufacturer may use different models for different project requirements, e.g. the validity of the harmonic impedance may be different for different level of details.
- Operation modes: some models, especially RMS models, may only be valid for specific operation modes.

5.6 Software to be used for validation

The key issues relating to the validation software are as follows:

- The model validation process and the verification of the generating unit capabilities shall be carried out in simulation software that can be chosen by the manufacturer or shall be undertaken in software requested by a system operator.
- The simulation model is normally created by the manufacturer in specific software, however the same model can be requested to be provided in different software that has been adopted by the system operator.

5.6.1 Software applicable for model validation

Currently, more and more manufacturers are developing models representing the behaviour of their generating units.

The models are used to predict specific behaviours of generating units, such as performance (steady state conditions) or other important phenomena associated with the specific technology.

The use of models to prove generating unit capabilities such as FRT is becoming a recognized approach by all involved parties since it becomes the only viable solution when the generating unit cannot be tested in a laboratory or site, typically due to its size (physical and power)

This is also reflected in the present European regulation EU 2016/631 requirements for grid connection of generators. Simulation models are addressed in art 15(6)(c) applicable to Type C and Type D power generating modules. Simulation models are also foreseen in multiple articles associated to the compliance process.

From a mere compliance perspective based on Equipment Certificates where the involved parties are the manufacturer, a testing institute and a Certifying body and where the scope of the model is limited to verifying the generating unit capabilities, the software on which the model is defined and the simulation software used for the verification are not relevant as long as the model and software capabilities allow the identification of the system characteristics, and the software and model performance have the expected accuracy required by the compliance process. In case of transferability of the results (described in the following section) the same should be expected.

However, there could be a different expectation by a system operator, mainly when they are expecting that the provided model is usable for their internal studies. The expectation is that the model provided is also a validated model (model transferability is covered in the next section).

Therefore, it seems that there are some different expectations as to what has to be provided.

On one side simulation models are expected to be used for compliance process and for system studies.

On the other side there is the expectation that the model provided is validated (eventually by a certifying body) and aligned to the software used by the system operator (including its latest version).

But model validation is a process that requires a considerable investment in term of costs and time, and it requires a high skillset from the manufacturers side, from the entity that is validating the model and from the system operator. Most of this investment needs to be repeated when transferring models with validation to other software.

The European regulation permits the relevant system operator to request a model in any of the considerable number of software packages that exist for simulations. The number increases if different versions of the same software product need to be included. Software licences can be costly (some software vendors consider different versions as different products, and additional licences are needed).

System operators are obviously reluctant to change their own software (unacceptable risk of losing data and information, developed solution, real time operation, etc).

Here are some possible recommendations associated to simulation software:

- Simulation software shall allow the integration of models created with the same software, but a previous revision (eventual min versions can be specified)
- Simulation software shall be compatible with open-source software (eg Modelica)
- Simulation software shall be compatible with other simulation software when it comes to manufacturer specific models.

It is also recommended that a wider harmonization among the different system operators exists regarding simulation software used is considered.

5.7 FRT capability using validated model / FRT characteristic transferability (different FRT characteristics)

Fault ride through capability is one of the main requirements generating units shall fulfil. It is expected that in case of a fault on the electrical system, generating units are to keep operating without disconnection from the grid.

The voltage profiles are frequently defined by rectangular shapes with the voltage associated with a specific time duration. Each of these shapes represents a different type of fault.

5.7.1 FRT requirement types

The fault ride through requirements at European level are described in the Requirement for Generator Network Code (EU)2016/631 in art. 14 and art. 16. Boundary condition shall be indicated by the system operator. The voltage profile shall be associated to a system grid and related characteristics to permit a proper analysis.

The present RfG code provides an under-voltage profile in art 14. The requirements as described in the RfG Network Code are applicable at the point of connection and they are expected to reflect the effects of a fault on the transmission system.

Fault Ride Through are today defined in the following terms:

1. Under Voltage Ride Through (UVRT) profile and
2. Over Voltage Ride Through (OVRT) profile

The FRT voltage profile is frequently described with different voltage profiles for SPGMs and PPMs. See the following example (taken from ENEDIS Enedis-PRO-RES_64E):

La figure suivante est introduite à titre indicatif pour faciliter la lecture et la compréhension de la réglementation :

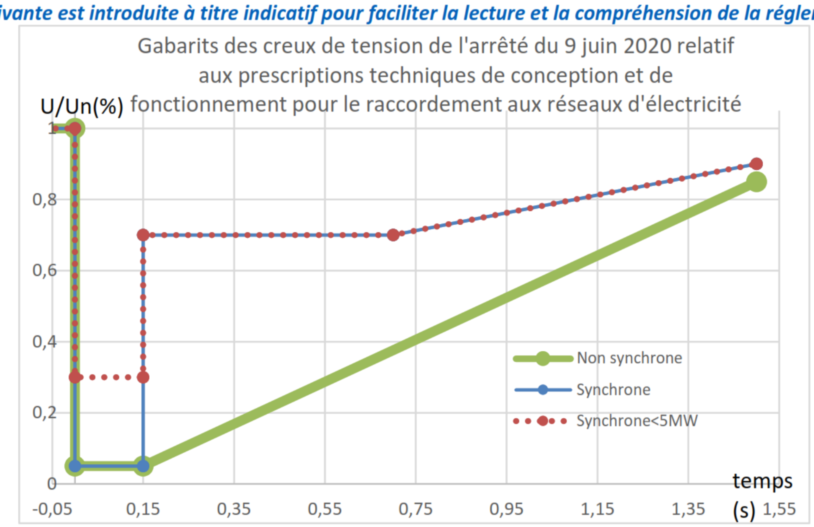


Figure 1– Gabarits des creux de tensions pour les différentes typologies d'Unité de Production

Figure 4 Example where PPM and SPGM requirements are different

In Europe the voltage characteristic representing UVRT and OVRT requirements can change from country to country. The requirements defined in the RfG code are applicable to Power Generating Modules and not power generating units. However, it can be expected that if the generating unit can cope with the requirements in the proximity of its terminals, then the generating unit can fulfil the requirements at the point of connection to the grid unless between the generating unit and the point of connection are installed electrical components that will worsen the fault condition. In this second case additional verification can be carried out using validated models and correspondent simulation of the system.

5.7.2 FRT verification using tests

To complete the verification scenario in terms of compliance, the grid information (e.g. Grid Short Circuit Power Scc and Grid characteristic X/R) is needed and shall be documented.

Generating units are requested to prove their capabilities against UVRT and OVRT profiles. When possible and feasible, generating units can be physically tested, so that a direct result can be recorded. FRT testing can be a complex and costly, especially when carried out on generating units that cannot be tested in laboratories mainly due to their active power size.

FRT tests can be carried out using tests containers (not in a laboratory), however this can have constraints in terms of the maximum power of the generating unit that can be tested. There could also be other constraints such as the tests having an impact on the grid or on the electrical system which are not acceptable to the grid operator or to the customer. Based on the variety of voltage profiles and the different parameters and settings that need to be verified, the number of tests could be considerably large.

5.7.3 FRT verification using models

As an alternative to testing, validated models can be used to prove compliance. It is considered that a validated model can be used to provide a reasonable level of confidence that the generating unit is capable of complying with FRT requirements (e.g. the generating unit model can be used to verify the capabilities at the point of connection to the grid).

There are two recognized approaches for validated models to be used for FRT verification:

1. A representative generating unit is tested (at least UVRT) and its model is validated based on the corresponding measurements.
2. The generating model is validated through tests which are not FRT (for example due to its size, its unicity, etc.). /

Dedicated software shall be used for a dynamic stability simulation. The baseline for such simulation shall be a simplified system that includes:

- Grid representation
- Interface busbars
- Transformers (when applicable or if part of the generating unit)

The validated model with its correspondent parameters and settings can be used to check the conformity with the different UVRT and OVRT profiles requested.

Compliance testing procedure frequently requires multiple tests and verifications to be carried out on the generating unit. When a validated model is in place, the same tests and verifications shall be carried out using the model via different simulated scenarios.

In case of transferability of FRT profiles (verification of compliance against profiles different than the one tested), the validated model can be used to verify different FRT profiles as long as these are less stringent in terms of retained voltage and/or clearing time, or within a 5% tolerance of the tested retained voltage and the same or shorter clearance time than those profiles used to validate the model.

5.7.4 Transferability of the FRT capability considering different system conditions

The system conditions play an important role on the capability of the generating unit to meet FRT requirements; These are the characteristics of the system to be considered (frequently expressed in terms of Short Circuit Power (Scc) and X/R ratio). The generating unit model is validated based on specific site test condition, which can be considered unique (test bench, test container, site conditions, etc.).

The principle is that once the generating unit model is validated, it can be used to check the behaviour of the unit under any system conditions. In the case of SPGU/SPGMs, the pass criteria in this case is to run a rotor stability analysis and check that the generating unit does not loose stability.

This transferability is important when it comes to certification process, since certification may refer to countries that can require different system conditions or may refer to site specific system conditions; the system conditions can be (and frequently are) different from the system conditions used for validating the model.

This same approach can be applied in case new requirements become applicable, for example at country level. The expectation is that certification can be updated using the simulation model.

In case of a family certification, the FRT verification (including multiple FRT scenarios) shall be repeated for each generating unit part of the family.

5.8 Transferability of FRT capability to other similar PGUs

Transferability of the FRT capability within the family focus on the following aspects:

- The model is validated based on specific site test conditions; transferability implies the use of the model to validate the FRT capability considering other specific site conditions or different FRT requirements (as long as they are less stringent in terms of retained voltage and/or clearing time, or within a 5% tolerance of the tested retained voltage and the same or shorter clearance time than the ones those profiles used for validation).

- The model is validated for a generating unit and the same results are transferred to similar generating units (generating units belonging to the same family) based on additional simulations performed on each family member.
- The model is validated for a generating unit based on a specific model software and the results may be transferred to a different model software; This will be possible by comparing the simulation results of both software packages and observing similar behaviour.

5.8.1 Transferability of the FRT capability among generating unit family member

The principle of a family of generating units is based on the fact that the generating units are very similar and therefore compliance tests can be carried out on a representative generating unit. The other members of the family are expected to share the same capabilities (capabilities are transferred from the tested representative unit to the others).

The transferability of the FRT capabilities is an exception. It is expected that the FRT capabilities are checked for each unit using the model validated of the representative generating unit.

A stability analysis (rotor angle in the case of SPGU/SPGM) shall be carried out for each of the members of the family considering same system conditions and with parameters and settings adapted to match each unit characteristics. The system and operation conditions to be used to verify the FRT capability shall be defined by the relevant system operator and shall be used to check all family members; this analysis may include simulating the compliance tests foreseen for validation of the capabilities (a simulated replica of a real test procedure).

The pass/fail criterium is that the stability analysis shows stable operating conditions at the end of the transient while recovering the (active) power to a specific value in relation to the (active) power before fault entrance. The certain value may be defined by the relevant system operator. In the case of SPGU/SPGMs, the rotor angle stability analysis shall show no pole slip and stable conditions at the end of the transient.

5.8.2 Transferability of model and results from a simulation software to a different simulation software

There are multiple simulation software packages that are available for transient and non-transient analysis. Software may not always permit an easy integration of a model created in a different software. The same is true for the same software, but different version.

The transferability of the model implies that the model representation in the original software and the one in the new software may differ when it comes to minor details; this may be necessary to adapt the way the different software packages run. The main structure is expected to be represented with a similar structure, same main parameters (as previously defined) and same settings.

The expectation is that the performance of the model in the original software and the other software are similar. This shall be verified by comparing simulation results carried out on the original software and on the other software. Simulations shall be carried out validating active power and reactive power behaviour (change in power setpoint), voltage variations (change in voltage setpoint), eventual grid code logic (simulate a frequency deviation and voltage deviation), fault behaviour (simulation of a fault on the grid).

As an alternative a complete model revalidation can be carried out using the original recordings. However, the expectation is that the model representing the same generating unit behaves similarly when used on different software packages and when considering the same requirements in terms of fidelity.

What is described above applies also when considering different versions of the same software. The expectation however is that the model implemented in former versions of the software can be seamlessly integrated in the later one (eventual minor changes expected). In this, a new validation is not expected if only minor adaptions are considered and no modifications to the model main structure occur.

5.8.3 Transferability of the result when the validation process is updated

Model validation can always be improved, in some cases this can have a major impact on previous validated models.

New requirements can add signals or information to the ones monitored during the validation process (and compliance testing). This can imply that the model needs to be updated to include the new information. This also could mean that measurements need to include the additional signal or information.

It's possible that the signal was already present in the model (and therefore there is no need to update the model). It's also possible that the signal or information had been already recorded during the tests.

If signals and information has been already recorded, but the model did does not include this, the model can be updated and validation can be repeated using the previously recorded data (data shall have been recorded by a measuring institute certified ISO 17025).

5.9 Model validity and maintenance

Preamble: the focus is the generating unit model, therefore the model associated to plant components are not considered.

Maintenance is a concept that can have a wide interpretation, but that can be sum up in two main subgroups: maintenance associated to an installed and operational generating unit and maintenance intended as part of an R&D activities made by manufacturers (of generating unit or components) to keep the models up to date with their latest configuration.

5.9.1 Model maintenance

The model is typically provided and associated with a new unit prior to its installation

Generating unit manufacturers normally provide a model that reflects the product sold as new, based on the latest information provided by the subcomponent manufacturer, and based on the compliance verification carried out. The manufacturer updates their models based on the product evolution and installed components.

In principle the model associated with a new unit installed does not need maintenance activities, as it does not suffer degradation associated with time. Depending on the technology the generating unit can have a lifecycle that typically spans from a decade to multiple decades, therefore it is possible that to keep its functionalities, the generating unit will need maintenance that include replacement of some components, or the generating unit can be updated for multiple reasons.

Maintenance activities are expected to be carried out by the generating unit owner (which can correspond with the plant facility owner) and they are typically considered a service.

There are several maintenance activities that can apply to the model during the lifecycle of the PGU:

- Model update associated with significant modernization of the generating unit
- Model update due to software simulation aging
- Model update due to new requirements (or system condition) applicable in the plant
- Model update due to plant change that trigger new requirements for existing units

When a component of the generating unit is replaced or updated, but the modification does not affect the model structure, it is expected that the model of the PGU, if existing, can be used with the updated parameters associated to the equipment to check the FRT requirements.

When a component that affects the dynamic behaviour is replaced or modified, this could trigger activities associated to model revalidation. As a general rule, significant modernization of a generating unit (see EG CSM final report) could trigger a review of the model.

5.9.2 Model update associated to significant modernization

Significant modernization is considered when modification occurs to the generating unit that affect its electrical characteristic (see also final report of EG Criteria for Significant Modernization (CSM)). When it comes to generating unit model, this can be understood as if a component (or more than one) of the generating unit, which affects the static or dynamic behaviour and therefore it is integrated in the model (including its parameters and settings), is replaced with a different one that requires a modification to the existing model (structure/representation, parameters and settings). Some typical examples applicable to synchronous units are the replacement of the existing AVR with a new one of different brand (or even same brand, new model due to aging) or adding a power system stabilizer to an existing unit. These changes can affect the model and potentially the previously results.

The replacement of existing components with same components does not require maintenance of the model.

Component replacements can imply re verification. EG HCF when defining family variants provide an example of verification that need to be undertaken. Model validation can be one of such activities.

In addition to component replacement, it can be requested to introduce a new control logic on the generating unit that can affect the generating unit performance. This can lead to a revision of the unit model that includes the new logics. This is true if the model is used for the verification of control logic or if the new logic can potentially affect the behaviour of the unit in case of FRT.

5.9.3 Model update due to software aging

The simulation model of a generating unit is prepared on specific software with a specific version. The software version may be updated after the generating unit has been installed and the compliance process has been carried out. If this occurs, the model associated to the specific installed unit is not continuously updated to the latest software version revision (it can still be used for the different system studies).

When it comes to compliance this is not relevant and therefore will not be further investigated. In case of model software update, the previous chapter covers this topic.

5.9.4 Model update needed to verify new/additional requirements

When it is requested to evaluate new system condition or requirements, there could be the need for an update. The requested update falls into the two previous categories (when components are modified to meet new requirements, when model need to be aligned to the software requested version).

5.9.5 Model updated due to plant changes that trigger new requirements for existing units

This case is similar to the previous chapter. The requested update falls into the first two categories (when components are modified to meet new requirements, when model need to be aligned to the software requested version).

5.9.6 Maintenance of the model as part of manufacturer R&D activities for new generating unit

Manufacturers are constantly developing their products to keep them in line with new requirements (Grid Connection requirements or Voice of the Customer) and many apply stringent quality control processes. In addition to normal quality cycle, installed component are subject to obsolescence, that means they are replaced with new components and the previous ones go out of production.

All these activities can lead to products that have different components and that can have a direct impact on the static and dynamic behaviour of the generating unit (normally improving it).

Maintenance activities associated to the model are part of the process. That includes when necessary, model re-validation and FRT requirements to be re-checked and eventually to update the certification.

It is not necessarily correct to assume that new certificates apply to generating units already installed and in operation; the certification applies for the unit with the latest components which can be different from the ones used on units in operation since several years. For such units the previous certificate (if existing) shall be used as reference.

Below a simplified flow chart of a manufacturers maintenance activities.

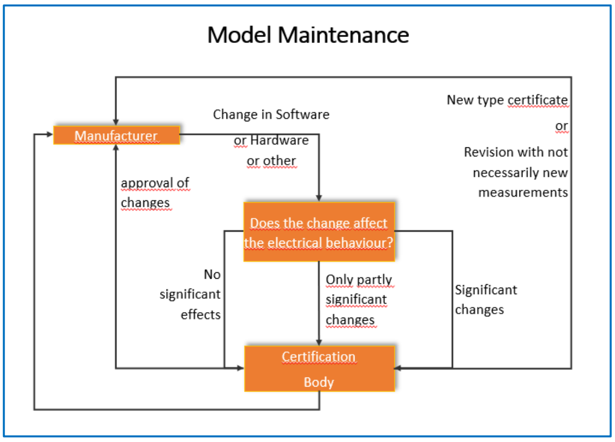


Figure 5 Model maintenance chart from manufacturers point of view

5.10 Encrypted Model / Black boxes

It is expected that the models used for verification simulations match, with a reasonable fidelity, the behaviour of the generating unit or the component they represent.

As a first approach, a library model can be used to represent a component. These models can be found (although not always represented the same way) in the many simulations' software used commercially.

For a library model to match the behaviour of a generating unit, an appropriate tuning of the parametrization is required. When the library model reasonably reflects the generating unit model or component, then it is possible that these could respect the fidelity requested and the parameters can be associated with the real parameters in the real unit.

However, in many cases ***these library models do not provide the fidelity requested.***

Library models also are not including specific logic (e.g. logic associated with Grid Code requirements). This additional logic can interfere with the overall natural behaviour, and they need to be included.

When the requested fidelity cannot be matched by the library model, then detailed specific models for the generating unit or the components of the generating units shall be used.

The detailed specific models can contain sensitive and/or proprietary information belonging to the manufacturer. Therefore, manufacturers cannot provide such models to avoid disclosure of sensitive proprietary information. To overcome this situation, it is permitted to use encrypted models where the proprietary and/or sensitive information cannot be accessed.

The encrypted models can be provided in two formats, as a black box of the complete generating unit (or the complete component) or as a model where some parts or structures of the model are unencrypted, and the sensitive parts are black boxes.

The encrypted models shall be used as the normal models. The encrypted part can be defined by input and output values, and the applicable settings and parameters as an unencrypted model. The manufacturer shall provide a description of the settings and parameters.

5.10.1 Certification process / model validation process

It can be expected that in case a certifying body is contracted by a manufacturer to validate the model against a level of fidelity needed (which can be referred for example to the level of fidelity requested in a specific country), a privileged agreement (non-disclosure agreement as minimum) between the parties shall be set in place. It can be expected a detailed level of information to be exchanged, for example the manufacturer can disclose or partly disclose the content of the black boxes.

The deliverable of the validation process will be an encrypted model (unless differently decided by the manufacturer).

The encrypted model will be accompanied with a list of possible settings and parameters applicable.

5.10.2 Encrypted model associated to different simulation software

An encrypted model transferability from a software to another follow the same process used for unencrypted model. This chapter also applies in case of same software and different version of the same software.

It is expected that the model in the different software is a replica of the original one including the black box set-up.

The model in the different software shall be properly validated. Comparing the behaviour of the models on one software with the one on the other software should be considered a reasonable validation criterion, when no or little differences are present when applying the same scenarios.

6 Harmonized equipment certificate for Type A

6.1 Introduction

Within the Expert group “Harmonization of Product Family Grouping and Acceptance of Equipment Certificates at European Level”, Subgroup III has been charged to develop a “Harmonized approach for equipment certificate for Type A”. The basis of the certification are the applicable requirements contained in Commission Regulation (EU) 2016/631, hereinafter referred to as “Requirements for Generators” or “RfG”.

In this document, the notions of “Power Generating Unit” (PGU) and “Power Generating Module” (PGM) are used.

A PGU can be defined as a single unit generating electricity, which is either synchronously or non-synchronously connected to the network or connected through power electronics.

A PGM can be a cluster of PGUs with a single point of connection (PoC) to an electric grid.

During the development of the harmonized approach, Subgroup III had to face a number of issues, which are described in the following paragraphs.

6.2 Objectives covered

6.2.1 Terms of Reference

According to the terms of reference (ToR) [1], the following objective will be covered:

"Provide a path for the creation of EU harmonized testing strategies and proof of compliance methods as well as a proposal on key criteria to meet requirements in RfG, taking into account existing strategies in other sectors of EU regulation."

The applicable deliverable from [1] is as follows:

"Recommendation on certification specification and procedure (including criteria for the acceptance of existing certifications that cover NC RfG requirements on EU countries)

This section will provide a proposal for a harmonized approach for type A certification.

6.3 Issues with Type A harmonization

The first step was to identify what were the main obstacles to achieve harmonization for Type A units.

6.3.1 Requirement reference: from PoC to unit terminals

For all PGU types (A, B, C and D), RfG requirements are referred to the Point of Connection (PoC). In order to make certification viable, however, requirements need to be "transferred" from POC to PGU terminals. This would make it possible to type-test PGUs in the factory, and thus to ascertain the capability to fulfil the requirements before on-site installation. Type-testing is particularly important for Type A PGUs, which are produced in extremely large numbers, and can hardly be tested on an individual basis.

As it happens, all requirements for Type A (frequency related functionality and possibly in the future voltage fault ride through capability) can be transferred from the PoC to the PGU terminals (see a detailed analysis in Annex II).

While this is a very favourable circumstance, it is not enough: a cluster of Type A PGUs can result in a higher type PGM, for example a Type B or a Type C. Therefore, Type B and C requirements, too, may need to be "transferred" from the PoC to PGU terminals.

Transfer of Type B and Type C requirements is not as straightforward as for Type A. However, it is still possible thanks to the following circumstances:

a) For most requirements, compliance at PGU terminals, is a sufficient condition for compliance at PoC (the only significant exception consists of requirements regarding reactive power, is addressed in Annex II). Such requirements can therefore be directly referred to PGU terminals, with no modification.

b) Other requirements are merely qualitative: in such cases, referral to PGU terminals rather than PoC is straightforward.

c) Type C compliance is a sufficient condition for Type B compliance, which in turn is sufficient for Type A compliance. Therefore, if a certificate is issued for a higher level PGM (for example a Type C), that certificate also proves compliance to lower type (A or B) requirements for all PGUs. Some exceptions need to be considered as mentioned in the respective articles in the NC RfG.

6.3.2 Country-specific threshold values

Requirements are qualitatively the same all over the EU. The differences among countries are the threshold values set by each country for each specific requirement. The only way to issue a certificate that is valid in all countries would be to test each requirement for its respective "worst case". However, this would probably be too challenging for most manufacturers.

Instead of making it compulsory to test worst case scenarios, it is considered more reasonable to let each manufacturer choose the countries for which to test their product. The certification approach should be harmonized rather than the requirements.

6.4 Proposal for a harmonized certificate for Type A PGUs

For each requirement, one single test is performed. The figure resulting from the test is then compared to each country-specific threshold value; this way, a judgement of "PGU complies with the requirement in the country" or "PGU does not comply with the requirement in the country" is given. If, and only if, a PGU is found to be compliant to all requirements for a country, overall compliance will be declared ("compliance" status for that country).

Standards EN 50549-1 and EN 50549-2 contain default threshold values. It would therefore be useful to add those standards in the list as an additional "countries", for a more exhaustive judgement of the PGU.

Tests may be performed as per EN 50549-10. However, a certificate issued for an individual requirement may replace the test for that requirement.

The umbrella concept for capability certification embodies the approach proposed. An example can be seen as follows:

As of issuing date of this certificate, PGU XXX complies with requirement 13-1-(a)-(i) (time period) in following Countries:

A	B	C	D
Country	Is the PGU compliant in the Country?	Threshold time period set by relevant TSO	Time resulting from type test performed on PGU
		min	min
Country 1	YES	40,00	60,00
Country 2	YES	50,00	60,00
Country	NO	65,00	60,00
...	...	...	...

Condition for compliance in each individual Country: value in column C<=value in column D

As of issuing date of this certificate, PGU XXX complies with requirement 13-1-(b) in following Countries:

A	B	C	D
Country	Is the PGU compliant in the Country?	Threshold ROCOF set by relevant TSO	ROCOF resulting from type test performed on PGU
		Hz/sec	Hz/sec
Country 1	YES	2,50	2,70
Country 2	YES	1,50	2,70
Country	YES	2,00	2,70
...	...	...	...

Condition for compliance in each individual Country: value in column C<=value in column D

As of issuing date of this certificate, PGU XXX complies with requirement 13-2-(a) in following Countries:

A	B	C	D	E	F	G
Country	Is the PGU compliant in the Country?	frequency threshold specified by the relevant TSO	Frequency resulting from type test performed on PGU	Is the PGU compliant in the Country?	Droop settings specified by the relevant TSO	Droop setting resulting from type test performed on PGU
		Hz	Hz		%	%
Country 1	YES	50,30	50,25	YES	5,00	4,00
Country 2	NO	50,20	50,25	YES	9,00	4,00
Country	YES	50,40	50,25	NO	3,00	4,00
...	...	...	...			

Condition for compliance in each individual Country:
value in column C>=value in column D AND
value in column F>=value in column G

As of issuing date of this certificate, PGU XXX complies with requirement 13-2-(c) in following Countries:

A	B	C	D	E	F	G
Country	Is the PGU compliant in the Country?	Lowest settable frequency threshold specified by RfG	Lowest settable frequency threshold resulting from visual inspection	Is the PGU compliant in the Country?	Highest settable frequency threshold specified by RfG	Highest settable frequency threshold resulting from visual inspection
		Hz	Hz		Hz	Hz
All Countries	YES	50,2	50,15	NO	50,5	50,55

Condition for compliance:
value in column C>=value in column D AND
value in column F<=value in column G

As of issuing date of this certificate, PGU XXX complies with requirement 13-2-(d) in following Countries:

A	B	C	D	E	F	G
Country	Is the PGU compliant in the Country?	Lowest settable droop threshold specified by RfG	Lowest settable droop threshold resulting from visual inspection	Is the PGU compliant in the Country?	Highest settable droop threshold specified by RfG	Highest settable droop threshold resulting from visual inspection
		%	%		%	%
All Countries	YES	2	1,5	NO	12	12,5

Condition for compliance:
value in column C>=value in column D AND
value in column F<=value in column G

This all then results in a certificate with a table similar to the following one:

As of issuing date of this certificate, PGU XXX complies with Article 13 in following Countries:

A	E
Country	**Is the PGU compliant in the Country?**
Country 1	YES
Country 2	NO
Country …	NO
…	

7 Harmonized approach for certification acceptance at EU level

7.1 Introduction

While the concept of equipment certificates has been introduced into the RfG's framework of compliance testing and compliance monitoring and, hence, into the processes of operational notifications for grid connection of PGMs, it remained quite vague. In particular, no formal references to standards, procedures and specifications as being imperative for conducting the sovereign task of certification have been included to the RfG. Moreover, a definition of equipment and its practical distinction between power-generating units (PGU), PGU components, power-generating modules (PGMs) / power-generating facilities (PGFs) and PGM components need further clarification.

Established as a product certificate, the equipment certificate shall essentially confirm the conformity of a PGU, a PGM or a component with specific grid connection requirements to any interested third party. Typically, such a certificate is solely issued with respect to a specific national grid code.

At the core of evaluation measures for product certification corresponding type tests on the equipment form the basis for the subsequent conformity assessment. However, as a common understanding today, equipment certificates may as well provide a validated simulation model with respect to the assessed electrical characteristics within the scope of the certificate. Typically, this validation is itself based on the type testing results.

Note: for equipment that is applied in type A PGMs only, a validated simulation model is in general not required, as – per RfG – a simulation on type A PGM level is not demanded.

Hence, PGU and component certificates provide a reliable, trustworthy basis for a subsequent conformity assessment on PGM level, e.g. in the framework of respective PGMDs, by providing

(1) evaluated type testing results on the equipment's characteristics with respect to defined testing standards, guidelines and regulations;

(2) additional third-party assessment on manufacturer's declarations on the functional design of the equipment that may have an impact on the specified requirements;

(3) a validated simulation model on the equipment's steady-state and dynamic behaviour with respect to the specified requirements, if applicable.

In this regard, equipment certification is especially fruitful for mass PGUs with high appliances on project level as demonstrated successfully in Spain and Germany where respective certificates have been applied for many years. Thus, equipment PGU and component certificates can effectively contribute to facilitate operational notification procedures throughout Europe.

Given that, the subgroup decided to focus on PGU and component certification and provide a comprehensive and applicable framework on these as more and more Member States are in the discussion to introduce such certification into their operational notification processes. Nevertheless, the report addresses the option of PGM certificates for the sake of completeness.

With this in mind, chapter 7.3 will start with a classification of equipment in term of PGUs, components and PGMs as to be applied in the course this report.

Based on these definitions, the formal background on certification will be provided (chapter 7.4 giving a special consideration to certification programmes and schemes for PGU and component certification and some general provisions on structure and content.

A status quo on the appliance of PGU and components certificates will be given with respect the outcome of subgroup 1 in chapter 7.5 as well as an outlook to international (future) standards on certification and testing.

Chapter 7.6, then, addresses the important reference, which requirements may be assessed in the course of the conformity statement of respective equipment certification. In view of the subgroup, a common understanding on the requirements and, hence, on the scope of validity will support the acceptance of certificates by relevant system operators within the operational notification process.

A practical recommendation on the introduction of a prototype status for new, innovative equipment and its handling in the notification process based on prototype declarations is introduced in chapter 7.7.

Some basic proposals on facilitating the acceptance are provided in chapter 7.8. However, the subgroup agrees, that further work must be spent on respective measures. For a better understanding, Chapter 7.9 will describe the general pathways how to utilize equipment certificates for subsequent conformity assessment on PGM level also for those countries that have not established a PGM certification definition. Chapter 8 also investigates the fact that for some facilities a PGU certification scheme may not be appropriate. With respect of the subgroup's focus on PGU and component level it has to be noted that this description remains on a high level and needs further elaboration by future expert groups.

The scope of this report is to create a common basis for equipment certification that is as harmonised as possible by

- providing a common understanding of the formal background on equipment certification;
- demonstrating the advantages of PGU and component certificates for the benefit of subsequent conformity assessments on PGM and facility level;
- opening additional pathways for certification by introducing more generic schemes on the requirements the certification is based on; hence facilitating their availability and deployment;
- providing information how PGU and component certificates may be applied in the course of conformity assessments on PGM and facility level.

7.2 Objectives covered

7.2.1 Terms of Reference

According to the terms of reference (ToR) [1], the following objective will be covered:

“Provide a path for the creation of EU harmonized testing strategies and proof of compliance methods as well as a proposal on key criteria to meet requirements in RfG, taking into account existing strategies in other sectors of EU regulation”

and

“Define an approach to accept certificates at EU level for all types (A, B, C and D). This can include a set of minimum requirements on respective statements of conformity, including the option of only selective conformity and the application of component certificates.”

The applicable deliverable from [1] is as follows:

“Recommendation on certification specification and procedure (including criteria for the acceptance of existing certifications that cover NC RfG requirements on EU countries)”

7.3 PGU-, component- and PGM-certification – a classification approach

In accordance with the Implementation Guideline Documentation (IGD) on Compliance Verification (2021) [9] [6] the following classification is proposed on equipment certification when applied in the context of Title III or Title IV of NC RfG.

7.3.1 Power-generating unit (PGU) certificates

'Power generation unit' or 'PGU' means an aggregation of components converting a primary source of energy into electricity at the terminals of the PGU.

The PGU certificate shall reasonably demonstrate the conformity of the PGU with the specified requirements at the PGU's terminals. The conformity assessment shall be based on the following evaluation schemes, if not otherwise stated in the certification scheme the PGU certificate is based on:

(1) Type testing results based on testing standards, guidelines and regulations and performed and published by an accredited testing laboratory according to ISO/IEC 17025 accreditation standard with the PGU as the device under test;

(2) Manufacturers declaration(s) on the PGU's capability as a comprehensible presentation of the functional design of the PGU with regards to the specified requirements to be assessed;

(3) A validation of a PGU simulation model on the steady-state and/or the dynamic fault behaviour of the PGU, if required;

(4) Component certificates according to section 7.3.2, if available and applicable.

If type testing has not been performed on the PGU under certification an application of other type testing results in the framework of family grouping according to chapter 7.4.4 is eligible.

The PGU certificate should unambiguously refer to one or more PGU simulation model(s) that have been validated according to a validation guideline that is defined in the certification scheme. If applicable, the simulation model shall be capable to the requirements of Article 15 (6) (c) and Chapter 5, 6 and 7 of Title IV of NC RfG, where applicable with respect to the type of PGU.

Typical component certificates that are included in PGU certificates are certificates on PGM controller or protection relays.

The certificate may be issued for one PGU or a defined set of PGUs under the framework of family grouping according to chapter 7.4.4.

A PGU certificate may be applied to facilitate a statement of conformity at the connection point of a PGM where the PGU is installed by

- steady-state and dynamic simulations executed with the validated PGU simulation model(s);
- straight forward application of the PGU's type testing results;
- calculations applying the PGU's type testing results.

Further information on the deployment of PGU certificates in the course of PGM conformity assessment is provided in chapter 7.9.

7.3.2 Component certificates

'Component' means any hardware element or software application having an impact on the electrical characteristics and /or operation of a power-generating facility, a power-generating module or a power-

[6] See: https://www.entsoe.eu/network_codes/cnc/cnc-igds/

generating unit. As examples, components can be a protection relay, an automatic voltage regulator, a power plant controller, a static synchronous compensator, a synchronous condenser, etc..

Hence, components may be part of a PGU or a PGM. Accordingly, PGU components and PGM components may have an impact on the compliance of the PGU and the PGM, respectively.

The component certificate shall demonstrate the conformity of the component with, in general, selected specified requirements which the component has an impact on. The conformity assessment shall be based on the following evaluation schemes, if not otherwise stated in the certification scheme the component certificate is based on:

(1) Type testing results based on testing standards, guidelines and regulations and performed and published by an accredited testing laboratory according to ISO/IEC 17025 accreditation standard with the component as the device under test;

(2) Manufacturers declaration on the component's capability as a comprehensible presentation of the functional design of the component with regards to the (selected) specified requirements to be assessed.

A component certificate may unambiguously refer to one or more component simulation model(s) that have been validated according to a validation guideline that is defined in the certification scheme. If applicable, the simulation model shall be capable to the requirements of Article 15 (6) (c) and Chapter 5, 6 and 7 of Title IV of NC RfG, where applicable with respect to the type of PGU.

It has to be noted, that within the certification programmes of Spain and Germany schemes on component certification is defined on the following components, only:

(1) PGM controller;

(2) Reactive power compensation devices (e.g. STATCOMs);

(3) Protection relays

(4) Equipment to facilitate FRT capabilities of PGMs.

As the unambiguous definition of a component and its interfaces to and interaction with the PGU and/or the PGM is essential for a clear and well-defined conformity assessment it is highly recommended to rely on these well-established certification schemes only.

7.3.3 Power generating module (PGM) certificates

The PGM certificate shall demonstrate the conformity of the PGM of type B to D with the specified requirements at the connection point. The conformity assessment shall be based on the following evaluation schemes, if not otherwise stated in the certification scheme the PGM certificate is based on

(1) applying the statement(s) of conformity on PGU(s) and component(s) installed in the PGM as provided in the equipment certificates of these PGU(s) and component(s);

(2) steady-state and dynamic simulations executed with the validated PGU model(s) and component model(s) (if applicable);

(3) documentation and declaration(s) by the manufacturer(s) of additional equipment installed in the PGM that does not provide an equipment certificate (e.g. cables, transformers, substations etc.)

(4) documentation by the relevant system operator on the network characteristics at the connection point and on specific setpoint and control parameters with respect to the specified requirements under certification.

Hence, a PGM certificate for power-generating modules of type B and C constitutes a PGMD issued by an authorised certifier according to Article 32 (6) of NC RfG. But also, for Member States that have not opted for

PGM certificates, the conformity assessment as defined in the certification scheme may provide an appropriate methodology how to conclude on the statement of compliance in the course of the PGMD according to Article 32 (1) of NC RfG to be provided by the PGF owner

Article 30 of NC RfG stipulates the submission of an installation document for type A PGMs by the PGF owner in the course of the operational notification procedure. The installation document does not include a systematic assessment of the PGM's compliance with the NC RfG requirements but rather some basic technical data of the PGM. The installation document may refer to equipment certificates. Nevertheless, the concept of PGM certification may be also applied to type A PGMs.

Note: in a fair approximation, a PGU certificate may substitute a PGM certificate for type A installations, if the PGM consists of only one respective PGU, the electrical distance between the PGU's terminals and the connection point is close and, in particular, if no transformer is installed in between.

7.4 Formal Requirements on Equipment Certification

The following general information is key to understand the formalities behind equipment certification as a whole.

7.4.1 Formal Framework – The ISO/IEC 17065 standard on product certification

The general framework for product certification is given in the international standard ISO/IEC 17065:2012 on the conformity assessment on products, services and processes. The standard defines the overall objective of each certification under its regime ***to give confidence to all interested parties that a product, process or service fulfils specified requirements. Hence, the value of certification is the degree of confidence and trust that is established by an impartial and competent demonstration of fulfilment of specified requirements by a third party.*** Notably, the standard

(1) provides **requirements on certification bodies** as authorised certifiers with respect to their independence and impartiality, their competencies and resources;

(2) describes the overall **conformity assessment process** (i.e. application ➔ evaluation ➔ review ➔ decision);

(3) defines the requirements on the **certification programme**, which serves as a working programme for any certification process and which shall comprise

   1. the **certification's scope**

   2. the **specified requirement** which the conformity assessment is based (these may be published in applicable product standards)

   3. the **evaluation and assessment methodologies** & **criteria**

   4. the **monitoring system** on the certificates' validity

Note: a certification programme may consist of one or several certification schemes. E.g. a certification programme on grid code compliance may consist of separate schemes on PGU, component and/or PGM certification. Further requirements on certification schemes as the core of the assessment regulation are given in the standard ISO/IEC 17067.

In the context of grid code certification

(1) the scope is defined as the conformity assessment of a PGU (and/or PGM) or its components with respect to the technical requirements on its grid connection;

(2) the specified requirement is, in general, given by the respective grid code;

(3) the evaluation and assessment methodologies (& criteria) are defined in testing, modelling, validation and/or simulation procedures;

(4) and the modalities of monitoring the certificates' validity may be applied within the overall compliance monitoring as required by RfG.

Note: testing, modelling, validation and/or simulation procedures may be part of the certification programme itself but also subject to separate standards, guidelines or regulations.

With regard to assessment criteria listed in the certification programme or underlying evaluation procedures it must be noted that these must not undermine any provisions already stipulated in the specified requirements.

Any authorised certifier issuing certificates on products, services and processes must hold a valid accreditation with respect to the standard ISO/IEC 17065, which is in general provided by the authorised certifier's national accreditation authority.

7.4.2 The central role of the certification scheme

Given this framework, the certification scheme according to ISO/IEC 17067 plays a significant role for the entire certification processes. Any certificate must uniquely reference the underlying certification programme.

The issuing authorised certifier must hold a valid accreditation with respect to this certification programme, as well as to the underlying specified requirements which, both, need to be listed in an annex to the authorised certifier's accreditation certificate.

Moreover, the regulation EA-1-22:2019 of the European Accreditation (EA) rules, that any certification programme, i.e. its conformity assessment scheme, needs to be evaluated once by one European national accreditation authority with regard to its suitability and complies with the requirements of ISO/IEC 17067 before an accreditation of single authorised certifiers can be granted.

In the European RfG context two certification programmes on grid code certification exist, namely:

(1) *Norma técnica de supervisión de la conformidad de los módulos de generación de electricidad* (NTS) *según el Reglamento UE 2016/631* (NTS SEPE; for continental Spain only) and
Norma técnica de supervisión de la conformidad de los módulos de generación de electricidad (NTS) *según el P.O.12.2 SENP* (NTS SENP, for Spanish islands only);
Programme owner: Red Eléctrica de España
Schemes covered: PGU certification (all technologies), component certification, project certification
Grid Codes addressed: Spanish BOE-A-2020-8965 – Orden TED/749/2020 and P.O. 12.2, respectively

(2) *Technische Richtlinie Nr. 8* (FGW-TR8)
Programm owner: Fördergesellschaft Windenergie und andere erneuerbare Energien (FGW e.V.)
Schemes covered: PGU certification (all technologies), component certification, project certification
Grid Codes addressed: German VDE ARs; but generally generic to other grid codes as well

Whereas in Spain the NTS comprises both the certification programme and further underlying procedures on testing, modelling, validation and simulation, the German FGW-TR8 is a certification programme only (with instructions on the simulation on PGM level), but refers to two more subordinate guidelines, FGW-TR3 on testing and FGW-TR4 on modelling and validation.

These certification programmes have been established in a many-years process under involvement of various stakeholder groups like equipment manufacturers, project developers, system operators, authorised certifiers, testing laboratories and others. In general, the duration until the appliance of a new Certification Programme and evaluation guidelines can be calculated up to 4-5 years at least: 2-3 years of collaborative development; 6-12 months on the initial accreditation of the programme (accreditation check according to EA-1-22:2019); 6

months on the accreditation of single authorised certifiers on this certification programme; 6-18 months on type testing and modelling, after new guidelines have been established.

As this process has not been started in most of the European countries so far, relevant system operators are encouraged to accept equipment certificates that have been issued based on the existing certification programmes above in order to meet the formal requirements on certification.

In several Member States guidelines have been issued providing information on the required scope and content of equipment certificates. However, it has to be noted, that these guidelines do no constitute certification programmes (nor schemes) in the framework of ISO/IEC 17067. In particular, these guidelines have not obtained an initial accreditation according to EA-1-22:2019, so far (see above). Nevertheless, these guidelines may be given a special consideration for equipment certification under the formal framework of an accredited certification scheme.

As provided by the standard ISO/IEC 17067 the certification programme shall define the specific evaluation schemes to be applied in the course of the conformity assessment. For product certification this is, in general, type testing of the underlying equipment. For grid code certification, also manufacturers' declarations on the functional design of the PGU's electrical system (i.e. parameter ranges, control modes, etc.) and the PGU's simulation model are to be considered for evaluation purposes.

For all evaluation manners it is required by ISO/IEC 17065 that the quality of this evaluation is defined, checked and ensured by the authorised certifier at all stages of the process. In general, quality measures are defined in the certification programme and/or underlying evaluation schemes (testing, modelling etc.). E.g., for type testing the test setup, the test sequence and the logging and documentation in terms of a test report are typically described in respective testing procedures – if not already included in the certification programme or the specified requirements (grid code) itself. Moreover, as part of the quality measures, the type testing typically has to be performed by an accredited testing laboratory according to ISO/IEC 17025 or to be witnessed by the authorised certifier as defined in the certification scheme.

At any time, an authorised certifier is responsible for handling deviations with respect to these testing and/or modelling/validation guidelines. In particular, when extending a national testing guideline to another country's grid code with different assessment criteria, the authorised certifier must provide a solid description on how to manage the deviant evaluation. Typically, this is done with an authorised certifier's *in-house scheme*.

Note: authorised certifiers' in-house schemes, just like superior certification programmes, are subject to the authorised certifier's accreditation and need to undergo an initial assessment by a national accreditation authority with respect to EA-1-22:2019.

Due to its obligation to ensure the quality of the entire evaluation process the authorised certifier shall also perform the model validation or shall contractually ensure and supervise the qualitative execution by third parties, if a model validation is required by the certification scheme.

7.4.3 General Structure & Content of PGU & Component Certificates

The general structure and content of PGU certificates is to be defined by the underlying certification programme the certificate is based on. Unless otherwise stated in the certification programme the following content shall be provided as a minimum (a * indicates, that the information shall be enclosed on the cover page of the certificate):

(1) Unambiguous type designation of the equipment to be certified *;

Note: if the equipment belongs to a product series which is jointly certified this product series shall be unambiguously declared.

(2) Type of the equipment (with respect to technology) *;

(3) Designation of the issuing authorised certifier, including a reference to its valid accreditation certificate according to ISO/IEC 17065:2012, i.e. the national accreditation authority's seal granted to the authorised certifier *;

(4) Certificate's unambiguous identifier *;

(5) Name and address of the certificate holder, usually the manufacturer of the equipment *;

(6) Designation of the specified requirements to which the conformity of the equipment is certified *;

(7) Designation of certification scheme(s) that has been applied and of further evaluation scheme(s) (if applicable) *;

(8) Brief, but complete conformity statement, designating any limitations of the equipment's conformity with respect to the specified requirements which the conformity assessment is based on; *;

(9) Indication of whether the equipment requires additional components to maintain conformity and whether these components must also be certified separately *;

(10) Designation of any limitations of the applicability of the certificate *;

(11) Date of issue and definition of the validity period of the certificate *;

(12) Full overview on the results of the conformity assessment (detailed conformity statement), indicating any limitations or additional remarks;

(13) Overview on the equipment's relevant technical data and software versions. Characteristic documents, i.e. manufacturers' declarations shall be indicated that describe that equipment or components in more detail;

(14) Schematic illustration of the main components, if applicable, illustration of communication interfaces between hardware components;

(15) A declaration on identity of the equipment with respect to the declared designation, the technical data and main components. A product series (or: family) that is jointly in the scope of the certificate shall be defined with reference to the varying components within the series. In contrast, equipment with the same designation but different technical design that is not under the scope of the certificate shall be explicitly excluded (if applicable);

(16) If applicable, clear designation of the components taken into account via a component certificate;

(17) Overview on type tests performed, indicating the reference on the test reports, the devices under tests, the performing testing laboratories and applied testing standards, guidelines or regulations. If equipment is certified within a product series, that has not been type-tested a rational justification shall be provided why testing results from other equipment with the product series may be applied;

(18) Name and identification number of the validated equipment's simulation model (if any). File name(s) and checksum(s) of the model file(s) as a 128-bit hash value generated according to Message-Digest Algorithm 5 (MD5);

Note: other measure to unambiguously identify the simulation model that corresponds to the certified equipment may be applicable.

(19) Designation of the software environment and its version number in which the equipment's simulation model was implemented and validated (if model exists);

(20) A reference to the manufacturer's quality management system (ISO 9001 certificate);

(21) The excerpts to the test reports (if available; may be attached as an annex to the certificate);

(22) The detailed evaluation report (may be attached as an annex to the certificate).

7.4.4 Product Series of Equipment for Certification – Family Definition

Typically, manufacturers provide a broad range of different equipment in product series with, in general, common core components, but slightly different characteristics of some technical features, e.g. a PGU's nominal power, rotor blades, etc.. Here, the concept of family grouping of such equivalent equipment enables a conformity assessment of the family as a whole based on a single type tested equipment within the family, only. Naturally, this concept cannot be applied to PGMs.

The application of the results of a conformity assessment, i.e., type testing, of one equipment to other equipment within a defined product family that does not provide defined evaluation measure is eligible based on the respective provisions of the certification scheme the equipment certificate is based on.

The family definition chapter offers a detailed description of how multiple units belong to a family, and what requirements can be transferred within the family.

For transfer of the results of a conformity assessment of SPGMs, the FRT stability of the non-tested SPGM under fault conditions shall be assessed by simulations. This shall be based on a validated model against the results of the tested SPGU that shall include the inner rotor angle behaviour; the angle must be validated and assessed to guarantee stability with enough reservation.

7.4.5 Validated PGU & Components Simulation Models

The certification scheme may require the issuance of a validated model along with the equipment certificate. In this case, provisions on the PGU simulation model implementation (i.e. RMS/EMT-presentation, modelling depth and control blocks, step width, etc.) as well requirements on the validation scheme are to be defined by the underlying certification scheme the certificate is based on or by subsequent technical guidelines (to be defined in the certification scheme).

The approach to obtain a validated model that can be used within the verification of conformity process is well described within the corresponding chapter.

For equipment that is applied in type A PGMs only, a validated simulation model is in general not required, as – per RfG – a simulation on type A PGM level is not demanded.

For system study purposes, the relevant system operator may define additional requirements on the software environment the PGU simulation model is executable in.

7.4.6 Selective Certificates

In general, the conformity statement of an equipment certificate shall comprise all assessment criteria provided by the specified requirements in accordance with chapter 7.6. In addition, equipment certificates shall be eligible where the conformity statement covers only selected specified requirements (e.g. FRT, LFSM, etc.).

The restriction of the conformity statement of such selective (or: partial) equipment certificates to the selected requirements shall be clearly indicated on the cover page of these certificates.

These selective certificates may be used to partly demonstrate compliance with the specified requirement as long as it shows compliance to the same or more stringent condition. This shall allow the PGFO to reduce the scope of pending testing, certification or compliance scope.

7.4.7 Validity of Certificates – Modification in Hard- & Software

The validity period of equipment certificates is to be defined by the underlying certification scheme the certificate is based on. As well a monitoring scheme for ensuring the certificate's validity when modifications on hard- and/or software are applied that might affect the certified characteristics of the equipment shall be defined in the certification scheme.

Certificates with unlimited validity shall not be accepted nor those based on certification schemes where no monitoring scheme on modifications of the equipment is implemented.

7.5 Status Quo on EU Equipment Certification and International Outlook

7.5.1 International Outlook

Up to now, no international certification programme for grid connection conformity assessment is available. However, two ongoing initiatives provide an outlook on standardised assessment and evaluation schemes for future consideration within the European certification on grid code compliance.

Within **IECRE** (IEC standards for renewable energy) the REMC WG 010[7] is working on a respective **Certification Programme**, that is planned to become available in the course of 2023. However, according to the IECRE statutes it will be applicable to renewable energy sources, i.e. wind energy, solar energy and maritime energy, only. Moreover, the certification programme will not provide a conformity assessment scheme for single national grid codes but rather enable a standardised approach for so-called capability certification. The programme has adopted the European definition of PGU and PGM. It has to be noted that IECRE will provide its own accreditation scheme (next to ISO/IEC 17065), where the accreditation is not awarded by the national accreditation authority but by IECRE itself. Hence, that international certification programme will require certification bodies to obtain an additional IECRE accreditation.

The **European testing guideline CLC TS 50549-10** (“Requirements for generating plants to be connected in parallel with distribution networks - Part 10: Tests for conformity assessment of generating units”) elaborated under CENELEC, which is currently available as a Technical Specification for voting, is about to be published by the end of 2022. CLC TS 50549-10 provides a type testing scheme for PGUs with respect to the technical requirements of the already published European standards EN 50549-1 and EN 50549-2 for grid connection of (RfG) type A and type B PGMs, respectively. Nevertheless, CLC TS 50549-10 also provides an option to be applied to grid connection requirements on other PGM types. Moreover, the testing guideline provides information how to expand the type testing to more stringent grid code requirements and also to a capability testing of the PGUs outmost technical capability. Hence, the guideline will serve as a valuable standard for compliance schemes in European member states where no national testing guidelines are in place as it provides an evaluation that can be directly used within certification programmes.

The feedback to the survey (Annex I, section 1.4) indicates that compliance documentation on power-generating units and components thereof, i.e. equipment certificates are currently applied in the following markets:

- Denmark
- Germany
- Italy
- Netherlands
- Poland
- Romania
- Spain

However, each nation has an individual approach, thus the manufacturers of type tested, mass produced products are obliged to involve themselves in repeating tests and certification processes in different nations

[7] REMC WG 010 „Grid Code Compliance“, see: https://test.iecre.org/dyn/www/f?p=110:6:0::::P6_ORG_ID:26127

that can prove both time consuming and expensive, having a negative impact on project plausibility and causing considerable delays to connection permission.

Additionally, it must be noted that not all of these countries provide a respective certification scheme for equipment certification nor provide a defined reference on existing certification schemes (cf. chapter 7.4.2).

7.6 Specified Requirements – Opening different Pathways of PGU and Component Certification

According to ISO/IEC 17065 the certification programme needs to define the specified requirements based on which the conformity of the equipment under certification is assessed. For equipment certificates on grid code compliance in the context of the ENC the respective specified requirement shall be one of the following as defined in chapter 7.6.1 and 7.6.2. A special focus is given to the more generic schemes in chapter 7.6.2, as they might provide a simplified approach for manufacturer to address multiple European Member State's requirements.

The following approaches are to be understood as options in order to meet the formal requirements of ISO/IEC 17065 on the definition of specified requirements. It is highly recommended that RSO (or: Member States on a superior level) will clearly define and make publicly available, which specified requirement they are willing to accept in the context of equipment certification (cf. chapter 7.8.2). A special focus shall be given to the acceptance of capability certificates according to chapter 7.6.2.3).

7.6.1 The Standard Approach – National Grid Code Certification

Here, the conformity assessment is based on requirements that have been set out as requirements of general application under the ENC regulations as established by relevant system operators or TSOs, approved by the entity designated by the Member State and published according to the provisions of the ENC. Accordingly, the specified requirements are, in general, provided by the national grid codes established by the Member States. It has to be noted, however, that these national grid codes do contain additional requirements in many cases and also may exceed the ENC exhaustive and/or non-exhaustive requirements with more stringent ones. Naturally, the conformity assessment will, hence, be extended to these broadened requirements given in the codes.

Any equipment certificate issued with respect to requirements as specified above will state the equipment's conformity to the national requirements, only. Hence, when applying these certificates in other countries with, in general, different grid code requirements there will be some gaps the statement of conformity of the equipment certificate might not cover. However, relevant system operators may also accept equipment certificates according to other grid code provisions under defined conditions (cf. chapter 7.8.2).

Note: where Member States have introduced distinct grid codes to cover the requirements for type A-D PGMs (or: requirements on different voltage levels the PGM is connected to) the conformity assessments with respect to these grid codes may typically be combined and issued in one equipment certificate.

National grid code certification is consistently – meaning: based on a clearly defined certification scheme – being applied in Spain and Germany. Other Member States also apply PGU certificates – mandatory or optional – within their operational certification processes, but do not refer to a normative framework, so far. The main advantage is, that the relevant system operators obtain a clear view on the equipment's conformity with respect to his specified requirements. A major disadvantage is, however, that manufacturer will have to provide multiple certificates according to the variety of national grid code specifications.

Note: manufacturer may choose to have multiple national grid codes being covered by one conformity assessment by performing the evaluation, i.e. type testing on the most stringent requirements of these codes. This approach is in line with the recommendations of subgroup III.

7.6.2 Generic Approaches for Umbrella Certification

In the following, three different ways of so-called umbrella certificates are introduced. The designation 'umbrella' is applied in order to demonstrate that these certificates may not only provide a conformity statement with respect to one (or a set of of) defined national grid code(s) (cf. chapter 7.6.1) but with respect to a generic framework of requirements that may take a manifold of national grid codes of different countries under its umbrella.

7.6.2.1 Certification with respect to RfG

The NC RfG itself can serve as a grid code specification for equipment certification, as it provides a full range of exhaustive requirements and also non-exhaustive requirements will provide assessment criteria with respect to their most stringent definitions (in general: their outer range). Respective equipment certificates may be called RfG certificates or RfG umbrella certificates.

Accordingly, the conformity assessment in this approach is based on the requirements as set out by the NC RfG and defined for the respective technology the equipment under certification belongs to (i.e., synchronous power-generating modules, power park module or offshore power park module). Where requirements are not defined as unambiguous parameters but as ranges, the most stringent criteria, i.e., parameter setting shall be subject to the conformity assessment. The RfG umbrella equipment certificate shall clearly indicate what type(s) A-D and synchronous area(s) the requirements applied for the conformity assessment refer to.

Where most stringent requirements for specific electrical characteristics may be determined by multiple criteria (e.g. capacity ranges combined with dynamic requirements) it is recommended that respective operating pointes subjected to the conformity assessment shall be chosen in line with the provisions of EN 50549-10 on such testing points.

As this certification may cover a lot of countries' needs to provide a substantial element in their grid code compliance schemes it is called a RfG certification.

RfG umbrella certificates may be issued NC RfG PGM type wise (PGM type A-D) or cover more than one NC RfG PGM type in one certificate.

It is highly recommended to apply the European Standard EN 50549-10 for the respective type testing to demonstrate compliance to the NC RfG requirements.

According to a study survey on the national implementation of NC RfG requirements within the European member states [8] several national NC RfG implementations do deviate from the ENC's definitions on exhaustive requirements or exceed the ranges for non-exhaustive requirements. Moreover, a lot of additional requirements have been introduced on national level, that have not been addressed by NC RfG at all (e.g. OVRT) or have been assigned to higher PGM types (e.g. reactive power controls, also required for type A or B PGMs in some national grid codes). Hence, a RfG umbrella certificate may not cover all grid code requirements of any relevant system operators. However, by addressing these gaps relevant system operators may also accept RfG certificates under defined conditions.

The concrete application of the certificate within the context of national grid code specification shall, then, be checked by the relevant system operator or a third party as specified by the relevant system operator.

Appendices to the RfG umbrella certificate may provide supplementary, country specific conformity statements which supply a clear, itemized overview on which national grid code specific requirements are met with the given conformity statement and which are not. It has to be noted that such an appendix may not be subjected to the accredited conformity assessment. The specified requirement the certificate's conformity assessment is based on is still the NC RfG.

[8] See: https://op.europa.eu/en/publication-detail/-/publication/7ff90e84-dae0-11eb-895a-01aa75ed71a1/

Also, this approach would provide a basis for a subsequent specific national grid code certification on this equipment according to 7.6.1, but restrict the testing and assessment efforts to those requirements that are not already met by the NC RfG requirements, only.

Where an equipment may not meet all most stringent requirements of the NC RfG a selective certificate may be issued on those requirements being met.

This approach provides a major advantage to the equipment's manufacturer as they can serve several European markets basically with one certificate.

Note: RfG certificates as outlined in this chapter have already been requested by some system operators in the past. However, in general these certificates had to include an additional statement on the conformity to the specific country or system operator requirements (typically including more stringent requirements). The "umbrella certification with respect to RfG" as described in this chapter can, thus, be used to demonstrate compliance to system operators or country specific requirements.

7.6.2.2 Certification with respect to EN 50549-1/-2

The European Standards EN 50549-1 and -2 have collected the European RfG implementation on type A and type B PGMs as available by the end of 2019, when the committee draft for voting was finalized. They therefore also include more stringent requirements where national grid code implementations have exceeded the non-exhaustive or even exhaustive requirements of RfG. As well, they include a manifold of additional requirements on these PGM types that have not been initially incorporated within the RfG, but haven been established in national grid code throughout Europe, like

- FRT capabilities for type A PGMs,
- OVRT capabilities,
- Requirements on protection systems,
- Requirements on reactive power controls,
- Requirements on power quality, etc.

The standards therefore provide an outer envelope around the most stringent grid code requirements as of 2019.

Respective equipment certificates may be called EN 50549-1/-2 certificates or EN umbrella certificates.

Accordingly, the conformity assessment in this approach is based on the requirements as set out by European standards on grid connection. As the standards define basically two different sets of requirements on each characteristic (*general* and *more stringent*) a respective equipment certificate shall clearly indicate on the cover page, on which set the conformity is based on.

A powerful argument for the usage of the EN standards as specified requirements is the fact that the corresponding standard EN 50549-10 provides a type testing guideline to demonstrate the equipment's compliance with the -1/-2 requirements.

As not all European member states have concluded their national RfG implementation by the end of 2019, the standards do not necessarily provide the actual provisions of all member states. Hence, a certificate according to EN 50549-1/-2 may not cover all grid code requirements of any relevant system operators. However, by addressing these gaps relevant system operators may also accept these certificates under defined conditions.

The concrete application of the certificate within the context of national grid code specification shall, then, be checked by the relevant system operator or a third party as specified by the relevant system operator.

Appendices to the EN 50549-1/-2-certificate may provide supplementary, country specific conformity statements which supply a clear, itemized overview on which national grid code specific requirements are met with the given conformity statement and which are not. It has to be noted that such an appendix may not be subjected to the accredited conformity assessment. The specified requirement the certificate's conformity assessment is based on is still the EN 50549-1/-2.

Also, this approach would provide a basis for a subsequent specific national grid code certification on this equipment according to 7.6.1, but restrict the testing and assessment efforts to those requirements that are not already met by the EN 50549-1/-2 requirements, only.

Where an equipment may not meet all most stringent requirements of the chosen EN standard a selective certificate may be issued on those requirements being met.

This approach provides a major advantage to the equipment's manufacturer as they can serve several European markets basically with one certificate.

7.6.2.3 Capability Certification

This approach neglects the application of grid code specifications in the course of conformity assessment at all. Instead, the conformity statement reflects the verification of the manufacturer's declaration on the PGU's outmost capability with respect to typical grid connection requirements.

Note: An example for the PGU's outmost capability in the context of FRT is given by the longest times the PGU can withstand very deep volt dips.

Accordingly, the conformity assessment in this approach is based on the outmost technical capability of the equipment with respect to general grid connection requirements as declared by the manufacturer of the equipment. Obligations for the manufacturer declaration on the equipment's capability shall be defined in the certification scheme.

Respective equipment certificates may be called capability certificates or capability umbrella certificates.

Notably, this conformity assessment in this approach can be based on type tests performed according to the European standard EN 50549-10 as this testing guideline also provides a procedure to evaluate the equipment's capability. Other well established testing standards like IEC 61400-21-1:2019 may be applied to facilitate a capability testing as well; the selection of testing parameters shall be agreed between the manufacturer, the testing laboratory and the authorised certifier.

The concrete application of the certificate within the context of national grid code specification shall, then, be checked by the relevant system operator or a third party as specified by the relevant system operator.

Appendices to the capability umbrella certificate may provide supplementary, country specific conformity statements which supply a clear, itemized overview on which national grid code specific requirements are met with the given conformity statement and which are not. It has to be noted that such an appendix may not be subjected to the accredited conformity assessment. The specified requirement the certificate's conformity assessment is based on is still the manufacturer declaration.

This approach is also supported by an upcoming international certification scheme within IECRE, which will provide a process to run a conformity assessment on the equipment's outmost technical capability as declared by the manufacturer.

It is obvious that this umbrella approach opens the option of the widest possible conformity confirmation of a PGU or component as more than its capability cannot be assessed and, potentially, confirmed. Moreover, it provides a cost-efficient way for manufacturers to subsequently demonstrate compliance to grid code specific requirements. Hence, it is strongly recommended that RSOs may accept respective capability certificates.

7.6.3 Overview

Figure 6 illustrates the interrelationship between the different specified requirements by national grid code, by the NC RfG, by the EN 50549-1/-2 provisions and the equipment's capability according to chapter 7.6.1 and 7.6.2.

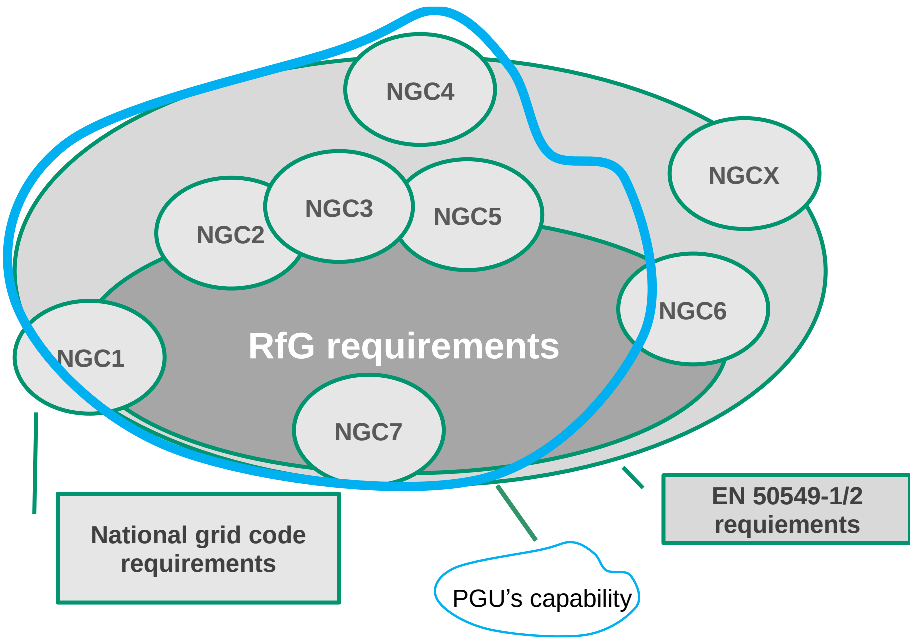


Figure 6: Illustration on different set of specified requirements on equipment certification

It should be noted that Figure 6 is primarily intended to illustrate the delineation of the four different definitions on specified requirements according to chapter 7.6.1 and 7.6.2. The European national grid codes as NC RfG implementations are in fact subsets of the NC RfG. In this regard, the national grid code requirements (NGCx) shown outside the NC RfG in Figure 6 are more for clarity of presentation.

7.7 Scheme on Prototype Definition & Prototype Declaration

As the type testing of a PGU is the starting point for its certification, which may take up considerable time to complete, a process shall be defined for new kind of GUs to obtain grid connection while the certification process has not yet been concluded. In Germany and Spain this has been addressed by introducing a prototype definition. For GUs of this prototype a temporary entitlement for grid connection without PGU and respective PGM certificates (in general PGMD for type B and C power-generating modules) shall be granted if a prototype declaration issued by an authorized certifier is provided, that enables a preliminary grid connection evaluation of the respective PGM where the prototypes are installed.

The following prototype definition and application is proposed:

A prototype is the first item of equipment (i.e. GUs or components) of a type that undergoes significant technical development or innovation, as well as any further item of equipment of that type that is put into service within two years of the first item of equipment of that type being put into service.

Significant technical developments and innovations are deemed if components or software versions are changed in such a way that the electrical behaviour of the equipment on the grid changes significantly or that an equivalent electrical behaviour is achieved by another technical development and innovation.

A prototype declaration issued by an authorized certifier shall demonstrate that the prototype PGU will be able to fulfil the requirements of general application established under the NC RfG, i.e. the national grid code. I.e., the prototype declaration shall comprise:

- A declaration of partial or full conformity to the requirements of general application established under the NC RfG;
- A declaration that this is a significant technical development or innovation;
- An indication of differences to existing and already certified equipment, if applicable;
- Further technical data according to the requirements of the respective grid code.

Within the two-year prototype status period starting with the commissioning of the first prototype equipment of this type, a prototype declaration is deemed to be equivalent to an equipment certificate in the course of the operational notification of power-generating modules under the provisions of Title III of NC RfG on the following conditions, unless the relevant system operator does not specify additional requirements on the operational notification of such prototypes:

(1) An equipment certificate is provided within the two-year prototype status period demonstrating the conformity to the requirements of general application established under the NC RfG at least to the same extend as stated by the prototype declaration

(2) The regular demonstration that the power-generating module complies with the requirements of general application established under the NC RfG is provided according to the provisions of Title III for the operational notification of type B, C and D power-generating modules within one year after the equipment certificate for the prototype equipment has been issued

The prototype declaration’s validity shall terminate with the end of the two-year prototype status or the publication of the respective equipment certificate, whatever is earlier.

If a prototype PGU fails to provide a PGU certificate within the two-year prototype status period the relevant system operator shall have the right to disconnect the respective PGU.

7.8 Recommendations on Measures to Increase the Acceptance of PGU & Component Certificates

Well-defined regulations on equipment certification on PGUs and Components as established in Spain and Germany are, in general, providing benefits to the stakeholders involved:

(1) **Manufacturers**, as they profit from defined requirements how to demonstrate compliance;

(2) **Project developers**, as they may profit from a third-party, independent proof on the conformity of products they want to apply in their projects. Furthermore, the PGU and/or component certificate provides a reliable bases to perform a conformity assessment on the PGM level of their projects and, hence, facilitate the operational notification process

(3) **System operators**, as they receive a reliable, third-party proof on the conformity of products that will be installed in their network. Furthermore, the PGU and/or component certificate provides a reliable bases to perform a conformity assessment on the PGM level for grid connection in their network and, hence, facilitate the operational notification process.

However, where such a system is not defined with respect to the formal requirements as stipulated in chapter 7.4, the acceptance is often limited due to lacking knowledge and approval on the general **formal background and definitions**, on the **requirements** as specified by the local relevant system operator and about the **general application** of such certificates. Therefore, the following measures are proposed to be considered in future ENCs in order to provide a well-defined framework in Europe.

7.8.1 Definitions on the general formal background

Today, the ENCs are missing a clear reference, that equipment certificates are product certificates according to the standard ISO/IEC 17065 and their issuance must, therefore, be based on a certification programme, i.e. respective schemes according to the standard ISO/IEC 17067. These references must be provided in future

ENCs in order to enhance the reliability when certificates are established under their regime and, thus, increase the acceptance of such certificates. For this purpose, the following amendments to the **definitions** of authorised certifiers and equipment certificates are proposed to be included in future ENCs:

(1) 'authorised certifier' means an entity that issues equipment certificates and power-generating module documents and whose accreditation according to ISO/IEC 17065 is given by a national affiliate of the European cooperation for Accreditation ('EA'), established in accordance with Regulation (EC) No 765/2008 of the European Parliament and of the Council (6);

(2) 'equipment certificate' means a document issued by an authorised certifier based on a certification scheme according to ISO/IEC 17067 for equipment used by a power-generating module, demand unit, distribution system, demand facility or HVDC system. The equipment certificate provides a statement of conformity demonstrating that specified requirements as defined on national or other level are fulfilled by the equipment. For the purpose of replacing specific parts of the compliance process, the equipment certificate may include simulation models that have been validated against actual test results;

As well, a well-defined **classification** on equipment and respective certificates will increase the ability to distinguish between different kind of certificates and to quickly identify their formal basis, their system boundaries and their scope of application. For this purpose, future ENCs should incorporate definitions on PGUs and components as well as on PGU, component and PGM certificates as stipulated in chapter 7.3.

Another measure to increase the acceptance on a formal basis is to ensure a minimal content of information, these certificates shall comprise. Therefore, future ENCs should incorporate minimal **requirements on content and structure** as listed in chapter 7.4.3.

Statements of conformity, e.g. provided by certificates, on equipment that has not been type-tested but where type-testing results are transferred from similar equipment within a type series often impose discussion on the eligibility of such transfers unless the rules and conditions are not clearly defined in terms of eligible family groupings. Therefore, future ENCs should specify this formal framework for the **certification of type series and family grouping** unless it is not defined in a certification scheme.

7.8.2 Requirements as specified by the relevant system operator

Whereas the recommendations as laid out in chapter 7.8.1 are suitable to provide a European-wide common formal framework on equipment certification, local issues on acceptance may arise from unclear specifications on behalf of the relevant system operator. In particular, the relevant system operator

(1) should specify which certification scheme(s) according to chapter 7.4 which the equipment certificates is based on are accepted;

(2) shall specify which specified requirements according to chapter 7.6 are accepted.

With respect to (1) relevant system operators are highly encouraged to precisely refer to a certification programme and/or scheme(s) they are willing to accept. For transparency reasons these programmes should be one of the existing superior schemes like the NTS or FGW-TR8 but not an in-house-scheme of one single authorised certifier unless such a in-house-scheme is not publicly available.

In future, IECRE might provide a standard programme for capability certification on grid code compliance. However, the "should"-specification in (1) provides the option for bi-lateral negotiations on certification schemes for application as this might become necessary where system operators are not familiar with existing schemes. In particular, for some national grid code implementation the application of the existing superior schemes according to chapter 7.4, like FGW-TR8 and NTS, may not be sufficient and additional provisions given by in-house-schemes of the authorised certifier need to be applied. Here, NTS or FGW-TR8 will provide the basis scheme with respect to formal requirements and general evaluation approaches whereas adapted in-house schemes might address specific extended evaluation measures to be applied on that grid code.

With reference to (2) it is assumed that the relevant system operator shall always accept equipment certificates, if any, that will provide a conformity statement with respect to the local grid code provisions as specified requirements ("national grid code certificates"). In order to support the appliance of equipment certificates throughout Europe to facilitate the respective operational notification processes relevant system operators are encouraged to specify which additional requirements might be accepted as base for a certificate's conformity assessment, i.e.

(1) requirements of national grid codes of others than those of the relevant system operator;

(2) requirements according to the NC RfG (RfG umbrella certificates, cf. chapter 7.6.2.1)

(3) requirements according to EN 50549-1/-2 (EN umbrella certificates, cf. chapter 7.6.2.2)

(4) requirements according to the equipment outmost capability (capability umbrella certificates 7.6.2.3)

A special focus should be given to the acceptance of capability umbrella certificates.

Optionally, relevant system operators may accept the recommendations proposed by the authorized certifier regarding the acceptance of these requirements based on existing equipment certificates. Nevertheless, it is recommended that the responsible system operator shall define and publish which specified requirements will be accepted in general.

According to chapter 7.6, gaps have to be expected between the requirements of the local grid code established by the relevant system operator and the requirements listed above. In these cases, a gap analysis is recommended to identify possible deficiencies of national grid code certificates in advance and to provide a transparent basis for the application of these certificates. These gap analyses shall not only consider gaps in the technical requirements but also gaps in the evaluation schemes that have been applied with the certificate but might not sufficient to demonstrate the requirements as specified by the relevant system operator.

Where gaps on compliance with respect to technical requirements are encountered or to be expected the relevant system operator shall specify what additional information shall be provided by the manufacturer or a third party in order to complete the conformity assessment. Possible measures and respective information are:

(1) References to existing further grid code certificates of the equipment with respect to other national grid code specifications that may close the open gaps;

(2) A rational evaluation of the extended manufacturer's documentation of the equipment, supplemented by simulations based on the equipment's validated model, if applicable. Manufacturer's prototype testing measurements may be considered as well.

(3) Rational information for further evaluation on PGM level (e.g., simulations, compliance testing).

Where authorised certifiers face a gap in the evaluation measures, e.g. the type testing performed on the equipment according to a given testing guideline does not fully demonstrate the equipment's capability, the following measures can be taken to complete the conformity assessment:

(1) The certification body may ask for extended type testing on the open issues. It may, hereto, define its own test plan or refer to the respective CLC TS 50549-10 provisions or other well established and mature testing guidelines such as IEC 61400-21-1 (wind industry) where applicable. These type testing results are, then, subject to the final conformity assessment.

(2) The certification body may perform the conformity assessment on the manufacturer's documentation of the equipment, supplemented by simulations based on the equipment's validated model, if applicable. The assessment shall be accomplished by rational and documented considerations and technical calculations by the certification body. Manufacturer's prototype testing measurements may be considered.

(3) The certificate may be restricted to those technical requirements where an unambiguously conformity assessment can be provided (selective certification, cf. chapter 7.4.6). The open issues are then subject to more detailed evaluation on PGM level (e.g., simulations, compliance testing).

7.9 Pathways to PGMD and Compliance Schemes on PGM Level by applying Equipment Certificates

In general, equipment certificates provide a reliable, trustworthy basis for a subsequent conformity assessment on PGM or plant level by providing:

(1) evaluated type testing results on the equipment's characteristics with respect to defined testing standards, guidelines and regulations;

(2) additional third-party assessment on manufacturer's declarations on the functional design of the equipment that may have an impact on the specified requirements;

(3) a validated simulation model on the equipment's steady-state and dynamic behaviour with respect to the specified requirements (if required by the certification scheme).

When these certificates are PGU component or PGM component (e.g. plant controller) related, a process to verify site specific compliance to the grid code requirements can be applied; this can be achieved by applying well established engineering methods like steady-state and dynamic simulations or computational evaluations, as well as specific on site testing; this can all be used to provide a final certificate or to produce the corresponding PGMD (either by the certifier or the facility owner).

The following flow down figure shows an approach found in the NTS which can be used as a basis for the process (where the term ACPGM corresponds to PGM components as introduced in chapter 7.3.2), if an authorised certifier is assigned to provide the final document:

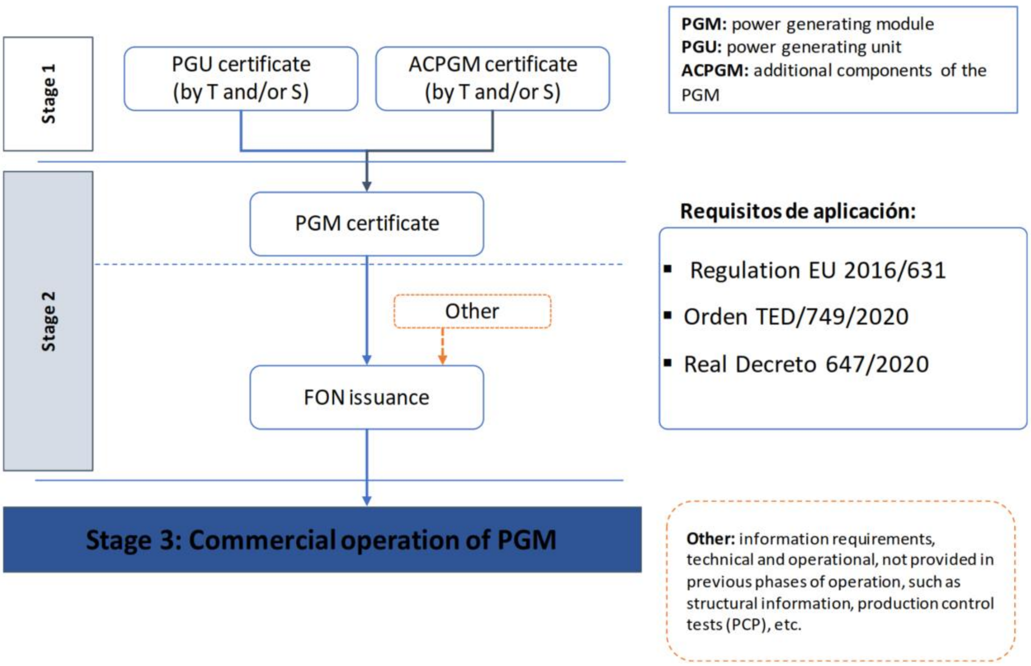


Figure 7 Stages in the general compliance monitoring scheme at PGM or plant level [5]

As seen above, the process would directly benefit from existing certificates obtained beforehand (stage 1) which would then be used directly within the site level analysis and final certification (stage 2). The following figure shows a detailed approach for obtaining the final PGMD or PGM certificate:

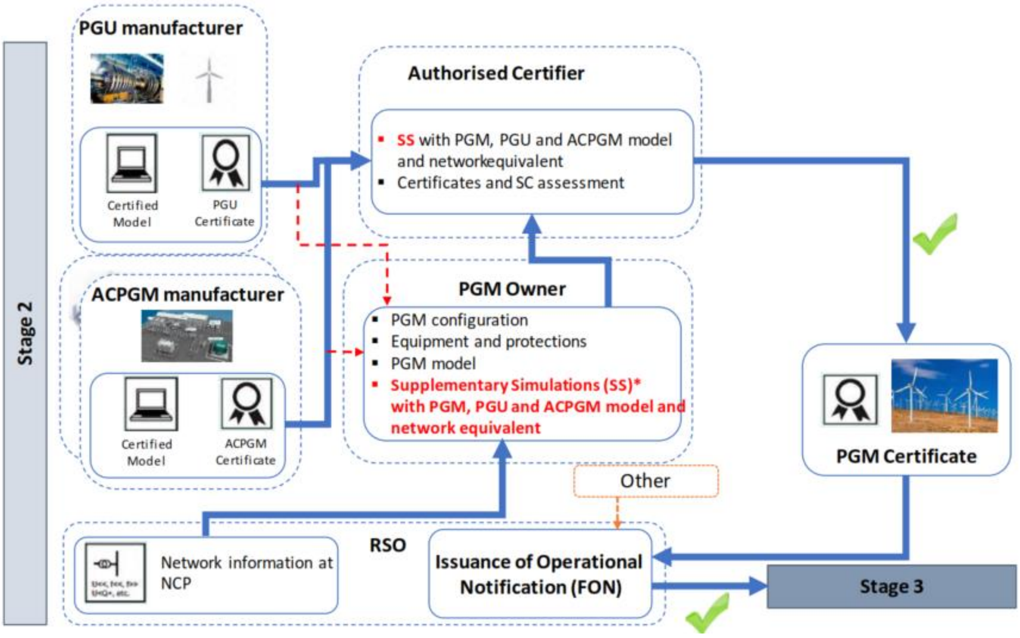


Figure 8 Scheme for obtaining the final PGM certificate from equipment certificates [5]

*SS stands for Simulation Studies

The on-site process would imply the following additional steps:

1. Evaluate existing equipment certificates and perform a gap analysis to determine what additional requirements need to be verified if the conformity statements of the certificates do not cover all requirements of the local grid code to be applied (cf. chapter 7.6 and chapter 7.8.2); this shall be performed by the relevant system operator or an authorized certifier (a third party)

2. Perform site specific studies based on the gap analysis; these can be additional supplementary tests or supplementary simulations to be performed (or checked) by a third authorized testing laboratory (when applicable)

3. All data shall be analysed by the relevant certifier or system operator and the corresponding certificate or permit shall be granted if all requirements have been verified.

Finally, it is to be stated that the IGD "General Guidance on Compliance Verification – Compliance Testing and Use of Equipment certificates" [9] has further elaborated a framework on how to apply EqCs within the compliance process on PGM level.

8 References

[1] EG HCF, ToR for Expert group: Harmonization of Equipment Certificate Acceptance at European Level and Product Family Grouping, 01/2022

[2] CEI, CEI-016, Reference technical rules for the connection of active and passive consumers to the HV and MV electrical networks of distribution Company, 03/2022

[3] ENA, G99 engineering recommendations amendment 9, 10/2022

[4] VDE FNN, Technische Anschlussregel Mittelspannung (VDE-AR-N 4110), 11/2018

[5] REE, Technical standard for monitoring the compliance of power generating modules according to EU Regulation 2016/631, V 2.1, 07/2021

[6] ISO, ISO 8528-6, Reciprocating internal combustion engine driven alternating current generating sets — Part 6: Test methods, DRAFT

[7] CENELEC: EN 50549-10:2022 – Requirements for generating plants to be connected in parallel with distribution networks - Part 10: Tests for conformity assessment of generating units; 2022

[8] International Electrotechnical Commission, IEC 61400-21-1:2019, Wind energy generation systems - Part 21-1: Measurement and assessment of electrical characteristics - Wind turbines, 05/2019

[9] ENTSO-E, IGD – General guidance on compliance verification – Compliance testing and use of equipment certificates, 07/2021

[10] COMMISSION REGULATION (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators (NC RfG); 2016

[11] International Electrotechnical Commission. IEC 17065:2012 – Conformity assessment -- Requirements for bodies certifying products, processes and services; 2012

[12] International Electrotechnical Commission. IEC 17067:2013 – Conformity assessment -- Fundamentals of product certification and guidelines for product certification schemes; 2013

[13] European Accreditation (EA): EA Procedure and Criteria for the Evaluation of Conformity Assessment Schemes by EA Accreditation Body Members (EA-1/22 A-AB); 2020

[14] Red Eléctrica de España: et alt Norma técnica de upervision de la conformidad de los módulos de generación de electricidad (NTS) según el P.O.12.2 SENP; 2021

[15] Fördergesellschaft Windenergie und andere erneuerbare Energien (FGW e.V.): Technische Richtlinie Nr. 8 (FGW-TR8) – Zertifizierung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie für deren Komponenten am Stromnetz; 2019 (rev. 9)

[16] Fördergesellschaft Windenergie und andere erneuerbare Energien (FGW e.V.): Technische Richtlinie Nr. 3 (FGW-TR3) – Bestimmung der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie für deren Komponenten am Mittel-, Hoch- und Höchstspannungsnetz; 2022 (rev. 26)

[17] Fördergesellschaft Windenergie und andere erneuerbare Energien (FGW e.V.): Technische Richtlinie Nr. 4 (FGW-TR4) – Anforderungen an Modellierung und Validierung von Simulationsmodellen der elektrischen Eigenschaften von Erzeugungseinheiten und -anlagen, Speicher sowie deren Komponenten; 2019 (rev. 9)

[18] FGH GmbH: Implementation of the Network Code on Requirements for Grid Connection of Generators; 2021; URL: https://op.europa.eu/en/publication-detail/-/publication/7ff90e84-dae0-11eb-895a-01aa75ed71a1; see also: WIW 2021, Paper WIW21-52.

[19] CENELEC: EN 50549-1:2019 – Requirements for generating plants to be connected in parallel with distribution networks - Part 1: Connection to a LV distribution network - Generating plants up to and including Type B; 2019

[20] CENELEC: EN 50549-2:2019 – 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; 2019

[21] International Electrotechnical Commission. IEC 60034-1:2022 – Rotating electrical machines - Part 1: Rating and performance; 2022

Annex I: Analysis of responses from Survey

This chapter presents the responses and analysis.

Answers to the questions are ordered in the tables with a row for each Member States. The table also includes a column for comments by the Subgroup members and may include both comments to the answers as well as additional information known by the subgroup member.

For each question there is also the analysis, where it has been meaningfully to write.

In general, the answers have been quite difficult to compare, and this seems to be the effect of very different implementations of RfG with respect to certification. The aim of this study is to find similarities, not differences. Therefore, where similarities are not visible, we have not performed deeper analysis.

1.1 General information and legislation

Question:

3.1.1 What are the sources of compliance requirements: national/regional grid code(s), other formal technical documents, national standards, etc?
Please name the sources and provide links or alternatively upload the documents.

Analysis:

Considering the results of Questionnaire and the provided contributions by the compilers, the following table shows the references and general information about the Legislation taken into account by each SOs of the EU member state filled the questionnaire:

Table 27 Summary for responses of question 3.1.1

Country	Description/Title of Standard/Rule/Act Answers by survey participants	Comments by EG members
Netherlands		
Poland		
Spain	Regulation (EU) 2016/631 and its national implementation made by Royal Decree 747/2020 and Orden Ministerial TED/749/2020. National compliance process is defined in the “Norma Técnica de Supervisión de la Conformidad” (NTS):	
Denmark	Not available from filled Questionnaire	
Germany	VDE-AR-N 4105 (TCR low voltage), VDE-AR-N 4110 (TCR medium voltage), VDE-AR-N 4120 (TCR high voltage), VDE-AR-N 4130 (TCR extra-high voltage), VDE-AR-N 4131 (TCR HVDC), FGW TG3 (testing guideline), FGW TG4 (model validation guideline), FGW TG8 (certification scheme)	
Italy	LINK of CEI 0-16 and CEI 0-21	
Romania	Not available from filled Questionnaire	

GB	The two key documents are Engineering Recommendations G98 (for a single generator of up to 16A in a single installation) and Engineering Recommendation G99 (for all other distribution connected generation). Both are freely available from www.dcode.org.uk	
Belgium	Test reports, Simulation study and VDE reports were accepted. "Synergrid C10/26 homologation procedure for power generating units" "Connection of type A and B generators have to follow rules in the Synergrid C10/11 prescription"	

Question:

3.1.2 (addition to 3.1.1)

Analysis:

On the following table are reported a brief description of content of rule, acts and standard of each EU member states that filled the questionnaire.

The following table, provide for a brief description of Legislative documents of each country, are directly provided by compilers of questionnaire. In general, they are information regard: implementation of RfG, in terms of threshold for each types of PGMs, in accordance of ranges provided by RfG itself, certification process and others information.

Table 28 Summary for responses of question 3.1.2

Country	Link of Standard/Rule/Act Answers by survey participants	Comments by EG members
Netherlands	Overheid.nl homepage with grid code https://wetten.overheid.nl/BWBR0037940/%20and%20https:/eur-lex.europa.eu/legal-content/NL/TXT/PDF/?uri=CELEX:32016R0631&from=NL Link to Netcode elektriciteit https://www.netbeheernederland.nl/_upload/Files/E02_-_Netcode_elektriciteit_112.pdf	
Poland		Only references to EU legislation are given
Spain	In spain the national threshold for Types B, D and D PGMs are: -Type B: connection point below 110 kV and maximum capacity	

	greater than 100kW and equal or smaller than 5MW. -Type C: connection point below 110 kV and maximum capacity greater than 5MW and equal or smaller than 50MW. -Type D: connection point equal or greater than 110 kV or maximum capacity equal to or greater than 50MW. In Spain, national thresholds for PGM type A are the following: -Type A: connection point below 110 kV and maximum capacity greater or equal than 0,8kW and equal or smaller than 100kW.	
Denmark	Guide for connection of pow-er-generating plants to the low-voltage grid (≤1 kV) is referred to Type A and B Version 1.2 - October 2021	The grid connection rules approved by the Danish NRA are provided and listed by the Danish TSO Energinet link. They are as follows. RFG - APPROVED THRESHOLD VALUES, RFG - APPENDIX 1 – REQUIREMENTS, RFG - APPENDIX 1A - GENERIC SIGNAL LIST, RFG - APPENDIX 1B - REQUIREMENTS FOR SIMULATION MODELS, RFG - APPENDIX 1D - REACTIVE POWER CONTROL PROPERTIES However, the mentioned Guide, provided by Green Power Denmark, is not approved by NRA. It is more like an unofficial guide on how to follow the approved rules.
Germany		
Italy	CEI 0-16 and CEI 0-21 are two National Standard implementing the RfG and European 50549 that has to be considered for connection of PGMs to distribution network in medium voltage level (0-16) and Low Voltage level (0-21). This standard allows to manage the connection process for all Type C generators directly connected to MV grid owned by DSO, type B generators directly connected to MV grid and LV grid, considering the thresholds for each type of generator determined in Italy. At the same type CEI 0-21 determine	

	the rules of connection of generators classified type A, in Italy the range of Type A is: 0,8 - 11,08 kW.	
Romania	certificates of PGM	
GB		
Belgium	Test reports, Simulation study and VDE reports were accepted. Refer to 3.1.3 for document details accepted and the following link	

Question:

3.1.3 If available, a link to compliance process document (or webpage explaining it) Please name the sources and provide links or alternatively upload the documents in the link below.

Analysis:

On the following table are reported the links to certification documents or modules provided by standard, rules and/or Legislation of each country filled the questionnaire:

Table 29 Summary for responses of question 3.1.3

Country	Link to Standard/Rule/Act Answers by survey participants	Comments by EG members
Netherlands	PPM's and SPGM's must be registered by the affiliate on https://energieleveren.nl/ Power-Generating Modules compliance verification, Power-Generating Modules type B, C and D according to NC RfG and Netcode elektriciteit: https://www.netbeheernederland.nl/_upload/Files/Regulering_20_1d4b9b30b6.pdf	The https://energieleveren.nl/ is for registering type A generators at the DSO.
Poland		
Spain	https://www.boe.es/buscar/act.php?id=BOE-A-2020-7439 Name: "*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*" https://www.boe.es/buscar/act.php?id=BOE-A-2020-8965	

	Name: "*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"* https://api.esios.ree.es/documents/648/download?locale=es Name: *"Anexo sobre los subapartados 5.6, 5.9 y 5.10 de la versión 2.1 (del 9/7/2021) de la NTS"*	
Denmark	https://en.energinet.dk/Electricity/Rules-and-Regulations/Regulations-for-new-facilities#Generationfacilities Name: *REGULATIONS FOR GRID CONNECTION OF NEW FACILITIES* https://www.danskenergi.dk/vejledning/nettilslutning/tekniske-regler-produktion Name *"Guide for connection of power-generating plants to LV grid, Guide for connection of power-generating plants MV and HV"*	
Germany		
Italy	https://www.ceinorme.it/strumenti-online/norme-cei-0-16-e-0-21/ *Name: Norme CEI 0-16 e 0-21* https://www.ceinorme.it/doc/norme/18309.pdf *Name: Regola tecnica di riferimento per la connessione di Utenti attivi e passivi alle reti BT delle imprese distributrici di energia elettrica*	

	https://www.ceinorme.it/doc/norme/18308.pdf *Name: Regola tecnica di riferimento per la connessione di Utenti attivi e passivi alle reti AT ed MT delle imprese distributrici di energia elettrica*	
Romania		
GB	https://www.energynetworks.org/assets/images/Resource%20library/ENA_EREC_G99_Issue_1_Amendment_8_(2021)0.1.pdf *Name: Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019* www.dcode.org.uk Name: *Licensed electricity distribution businesses, or Distribution Network Operators (DNOs) in Great Britain, are obliged under Condition 21 of their licences to maintain a Distribution Code detailing the technical parameters and considerations relating to connection to, and use of, their electrical networks.*	
Belgium	http://www.synergrid.be/download.cfm?fileId=tekst_website_final_v2.pdf Name: *Synergrid C10/26 homologation procedure for power generating units*	

1.2 Process - Conformity assured by scheme for type approval (general product test) - primarily Type A

Question:

3.2.1 If there exists a positive list for Power Generation Units in the selected Member State - who is the "key body" in the approval process? (Typically, the body who keep a public accessible list of compliant units)

Analysis:

Some countries like Poland, Germany, Romania, Demark, United Kingdom and Belgium have a list of approved power generation units. Some countries do not have such lists, but each connection is evaluated in accordance with the national standard and the certificates are verified.

Table 30 Summary for responses of question 3.2.1

Country	Key body who maintains the public list Answers by survey participants	Comments by EG members
Netherlands	N/A The Netherlands uses a list of approved inverters from Synergrid in Belgium for the compliance verification process	
Poland	PTPIREE	
Spain	N/A	
Denmark	Green Power Denmark https://www.danskenergi.dk/vejledning/nettilslutning/positivlister Dansk Energi	Clarification: Dansk Energi is now part of Green Power Denmark,
Germany	FGW https://wind-fgw.de/	
Italy	Italy there is ANIE, a National Association of Electric and Electronic Enterprises; the members are also manufacturers of PGMs or PGUs. ANIE pubblishes and updates periodically a list of generators certified in accordance of requirements specified by CEI 0-1a6 and CEI 0-21. Not all Electric Industries are members of ANIE.	
Romania	License required for market access. ANRE list	
GB	ENA type registry mainly Type A generators are mandatory recorded. www.ena-eng.org/gen-ttr/	
Belgium	Synergrid http://www.synergrid.be/index.cfm?PageID=20872#	

Question:

3.2.2 What documentation etc is required for the approval by the key body? Please identify or describe the requirements and provide links or alternatively upload the documents.

Analysis:

In most of the countries a certificate is necessary, alternatively some countries accept test reports along with manufacturer declaration and validated simulation model. This varies region from regions and depending on independent system operators. Types of documents required by some countries are shown below.

Table 31 Summary for responses of question 3.2.2

Country	Documentation required for conformance Answers by survey participants	Comments by EG members
Netherlands	https://www.netbeheernederland.nl/_upload/Files/Regulering_20_a3eb9ede21.pdf	
Poland	Certificate required	
Spain	Certificate required	
Denmark	N/A	
Germany	Unit certificate, Protection certificate, component certificate	
Italy	Refer to national standard. Certificate if available is acceptable. Else test reports with model and manufacturer decleration is acceptable	
Romania	All technical data and NFF	
GB	Certificate if available, or test reports and model is to be submitted with decleration	
Belgium	1. Declaration of conformity 2. List of power generating units 3. Checklist annex D (technical file) 4. Proof of conformity documents	

Question:

3.2.4 Is your organisation involved with any third-party organisation in the type-approval process, such as notified certification bodies (EU 2008/765) EN 17065? Testing bodies EN 17025? Regulators? Please name third party organisations and provide links.

Analysis:

The survey was answered by authorized certification body, TSO and manufacturer. Some appeared to be involved with third party organizations and some lacked this info. Details can be found below

Table 32 Summary for responses of question 3.2.4

Country	Third party involvement for type approval Answers by survey participants	Comments by EG members
Netherlands	Yes certifier is involved	
Poland	Yes certifier is involved.	
Spain	Yes certifier is involved as defined in section 12 of NTS	
Denmark	N/A	
Germany	Yes certifier and testing agency are involved.	

	https://wind-fgw.de/wp-content/uploads/2022/04/220420_FGW_Zulassung_verantwortlicher_Personen.pdf	
Italy	No. DSOs acquire all information (certifications, technical report and all foreseen by the National standard) about the connecting PGMs process.	
Romania	No	
GB	Not mandatory, but if certificate and test reports from approved bodies are accepted.	
Belgium	No	

Question:

3.2.5 Can multiple units from a same product family (or variant such as different voltage) be certified with one set of tests? (Family definition)

Analysis:

Some countries with one set of test multiple units can be certified as variants or product family. But in some countries it is not applicable. List of acceptance and non acceptance of product family certificaiton can be found below.

Table 33 Summary for responses of question 3.2.5

Country	Acceptance on family or variants Answers by survey participants	Comments by EG members
Netherlands	N/A	
Poland	N/A Yes, same definition as in Germany (mentioned by PTPiREE by email)	
Spain	Yes. This is allowed if they are of the same technology and similar capacity (25%). See Section 4.5 in NTS for further details	
Denmark	N/A	
Germany	Yes	
Italy	This is allowed for EESS having the same technology, number of phase, same typology of storage elements	
Romania	No	
GB	Yes	
Belgium	Yes	

Denmark – Attestation of conformity from EU notified Body (ISO 17065)

United kingdom - It is indicated on the type test register: the statuses are "compliant"; "compliant - on site confirmation by DSO required"; "Further information required - non compliant"; "Further information required - minor non-compliance or document error"; "Awaiting assessment"

Belgium - List on Synergrid website

1.3 Compliance reports on Power Generation Unit and component level

Question:

3.3.1 In what circumstances is physical testing used for producing the documentation and reports?

Analysis:

Table 34 Summary for responses of question 3.3.1

Country	Appliance of physical testing (PGU) Answers by survey participants	Comments by EG members
Netherlands	For type A requirements	
Poland	Required for all provisions that can be tested	No testing procedure available. Approvement by certication body
Spain	Required (abgestuft) according to NTS (certification scheme, including testing procedures)	
Denmark	Onsite testing in course of ION only (Cerios DSO, DK) But: always required (EC Power DK)	For type A and B requirements equipment certificates may be applied in order to provide verification (see: Guide for connection of power-generating plants to the low-voltage grid; https://www.danskenergi.dk/files/media/dokumenter/2021-10/Guide%20for%20connection%20of%20power-generating%20plants%20to%20LV.pdf)
Germany	Required (i.g. full type-testing) according to FGW-TR8 (certification scheme, with reference to testing procedure FGW-TR3)	
Italy	Required	No link to testing procedure given, but it should be CEI-016
Romania		

GB	Onsite testing in course of ION optional; accredited institutes only	
Belgium	Onsite testing in course of ION optional; accredited institutes only	

Question:

3.3.2 In what circumstances are simulations used for producing the documentation and reports? Do you have available examples of simulation reports? (ie. only if they can be published)

Analysis:

Table 35 Summary for responses of question 3.3.2

Country	Document Answers by survey participants	Comments by EG members
Netherlands		
Poland		
Spain		
Denmark		
Germany		
Italy	Specific simulations for rotating generators are applied where real tests with dedicated test benches are not feasible	
Romania		
GB		
Belgium		

Question:

3.3.6 What documentation (if any) do you produce (or receive) that is project specific?

Analysis:

Table 36 Summary for responses of question 3.3.6

Country	Document Answers by survey participants	Comments by EG members
Netherlands		

Poland		
Spain		
Denmark		Templates used for the for the notification of grid connection of a new generator. Annex connection of power-generating plants to the low-voltage grid (≤1 kV) - Type A and B - Version 1.2 (link) Annex for connection of power-generating plants to the medium and high-voltage grid (>1 kV) - Type B, C - and D - Version 1.1 (link)
Germany		
Italy		
Romania		
GB		
Belgium		

Question:

3.3.7 In case simulation reports are accepted, is there any specific request on the software to be used for simulation?

Analysis:

Table 37 Summary for responses of question 3.3.7

Country	Software Answers by survey participants	Comments by EG members
Netherlands	PSS/E; Power Facoty	
Poland	Not defined	
Spain	Not defined	
Denmark	Not defined	
Germany	Not defined	
Italy	Not defined	
Romania	Not defined	
GB	Not defined	

Belgium	Not defined	

1.4 Compliance documentation on Power Generation Unit and components thereof - Equipment Certificates

Question:

3.4.1 How are Equipment Certificates defined? What documents define the requirements and procedures

Analysis:

Table 38 Summary for responses of question 3.4.1

Country	Document Answers by survey participants	Comments by EG members
Netherlands	No definition provided	
Poland	Defined in: https://www.pse.pl/documents/20182/7be20018-80ad-47a9-8683-4e9a8132ca3e?safeargs=646f776e6c6f61643d74727565 (Polish only)	
Spain	Accredited certification programme: Norma técnica de supervisión de la conformidad de los módulos de generación de electricidad (NTS) según el Reglamento UE 2016/631 (NTS SEPE; for continental Spain only) and Norma técnica de supervisión de la conformidad de los módulos de generación de electricidad (NTS) según el P.O.12.2 SENP (NTS SENP, for Spanish islands only) Specification: Spanish BOE-A-2020-8965 - Orden TED/749/2020 and P.O. 12.2, respectively	
Denmark	No definition provided	Document “Guide for connection of power-generating plants to the low-voltage grid (≤1 kV)” enables the application of equipment certificates, but does not provide a definition on these.
Germany	Accredited certification programme: Technische Richtlinie Nr. 8 (FGW-TR8); FGW e.V., 2019; Specification: VDE AR-N 4105/10/20/30:2018;	Contributing documents: FGW-TR3 (testing guideline for type B, C, D requirements); FGW-TR4

	Legal link: Elektrotechnische-Eigenschaften-Nachweis-Verordnung (NELEV), 2017	(modelling & model validation guideline; PGU level); DIN VDE 0124-100 (testing guideline for type A requirements)
Italy	No definition provided	Reference to CEI-016 & CEI-021 which include testing requirements
Romania	No definition provided	*Reference to IGD given*
GB	No definition provided	*Reference to IGD given*
Belgium	No definition provided	

Question:

3.4.2 What equipment certification types are there (component, unit, module, facility)

Analysis:

Table 39 Summary for responses of question 3.4.2

Country	Level of Certification Answers by survey participants	Comments by EG members
Netherlands		
Poland	Component	
Spain	Component, PGU, PGM	
Denmark		
Germany	Component, PGU, PGM, Facility	
Italy	PGU	A facility has to consist in all single compliant PGUs and results automatically compliant.
Romania	PGU, PGM	
GB		*Reference to RfG given*
Belgium		

Question:

3.4.5 Please give the name of any involved organisations, institutes etc.

Analysis:

Table 40 Summary for responses of question 3.4.5

Country	Document Answers by survey participants	Comments by EG members
Netherlands	Netbeheer Nederland	
Poland	PSE	
Spain	RED	
Denmark		
Germany	Fördergesellschaft Windenergie und andere Erneuerbare Energien (FGW) e.V.	
Italy		
Romania		
GB		
Belgium		

Question:

3.4.6 Please name the testing guidelines. Please provide links here or upload documents (below) if possible.

Analysis:

Table 41 Summary for responses of question 3.4.6

Country	Document Answers by survey participants	Comments by EG members
Netherlands	Power-Generating Modules compliance Verification - Power-Generating Modules type B, C and D according to NC RfG and Netcode elektriciteit; Netbeheer, 2021 Link https://www.netbeheernederland.nl/_upload/Files/Regulering_20_1d4b9b30b6.pdf	
Poland	Not defined	

Spain	NTS (see 3.4.1) alternatively, FGW-TR3 is sufficient (see above, Germany) Link https://aelec.es/wp-content/uploads/2021/07/20210709-NTS-SEPE-v2.1.pdf https://aeeolica.org/wp-content/uploads/2021/08/Norma-Tcnica-de-Supervisin-SEPE-v2.1_Ingls.pdf	
Denmark		
Germany	Technische Richtlinie Nr. 3 (FGW-TR3) (for type B, C, D requirements); DIN VDE 0124-100 (for type A requirements) Link https://wind-fgw.de/shop/technische-richtlinien/ https://www.vde-verlag.de/normen/0100571/din-vde-v-0124-100-vde-v-0124-100-2020-06.html	
Italy	CEI-016 & CEI-021 include testing requirements	
Romania	Not defined	
GB	Not defined	
Belgium		

Question:

3.4.8 Minimum scope. please provide description and/or link

Analysis:

Table 42 Summary for responses of question 3.4.8

Country	Scope Answers by survey participants	Comments by EG members
Netherlands	See documents above (chapter 3.4.6)	
Poland	See: http://ptpiree.pl/opracowania/kodeksy-sieci/warunki-i-procedury	
Spain	See documents above (chapter 3.4.6)	
Denmark		
Germany	See documents above (chapter 3.4.6)	

Italy	See documents above (chapter 3.4.6)	
Romania		
GB		
Belgium		

Question:

3.4.10 Please state the titles etc of any modelling and/or validation guideline:

Analysis:

Table 43 Summary for responses of question 3.4.10

Country	Document Answers by survey participants	Comments by EG members
Netherlands	IEC 61400-27-2	
Poland	FGW-TR4 is accepted	
Spain	NTS (see 3.4.1) alternatively, IEC-61400-2 or FGW-TR4 is sufficient (see above, Germany)	
Denmark	Not provided	
Germany	Technische Richtlinie Nr. 4 (FGW-TR4)	
Italy	CEI-016 & CEI-021 include validation requirements	
Romania	Not provided	
GB	Reference to G99 which includes requirements on models	
Belgium	Not provided	

Question:

3.4.14 In case a simulation model is or can be part of Equipment certificate, is it requested the model to be compatible with any specific software? The manufacturer can develop the model on its specific software?

Analysis:

Table 44 Summary for responses of question 3.4.14

Country	Document	Comments by EG members

	Answers by survey participants	
Netherlands	Power Factory; PSS/E	
Poland	Not provided	
Spain	Not provided	
Denmark	Not provided	
Germany	Not provided	
Italy	Not provided	
Romania	PSS/E; Eurostag	
GB	Not provided	
Belgium	Not provided	

Question:

3.4.15 Is there a process for family of units certification using simulation and is there any specific requirement on the software to be used?

Analysis:

Table 45 Summary for responses of question 3.4.15

Country	Document Answers by survey participants	Comments by EG members
Netherlands	Not provided	
Poland	German provisions are accepted	
Spain	Defined in NTS	
Denmark	Not provided	
Germany	Defined in VDE AR-N 4105/10/20/30:2018 as well as operationalised in FGW-TR8	
Italy	Not provided	
Romania	Not provided	
GB	Not provided	
Belgium	Not provided	

1.5 Documentation at installation site – commissioning

To complete the approval process, different types of documents and proofs are needed based on country specific requirements. The notification of compliance can be done either through site test reports, simulation reports, PGMD documents and/or declarations of conformity. This section covers the responses from the different participants on this topic.

The following are summaries of each question and the responses received.

Question:

3.5.1 What are the documents necessary for the approval of the PGM and/or the power generating facility (Templates etc. should be available from Relevant System Operator) Please name the sources and provide links or alternatively upload the documents (below).

Analysis:

This section shows a summary of the type of documents needed to obtain PGM connection approval.

In summary, there is a wide approach of types of documents required that can be summarized as follows:

- PGMD document (Netherlands, Denmark, UK)
- Physical tests (Netherlands, Poland, Denmark, Romania)
- Simulation report (Netherlands, Denmark, UK)
- Statement of compliance (Netherlands, Denmark, UK)
- PGU Certificate (Spain, Germany, Romania)
- Plant certificate (Spain, Germany)
- Homologation (Belgium)
- Type certificate (UK)

The following table shows the summary of all responses:

Table 46 Summary for responses of question 3.5.1

Country	Document Answers by survey participants	Comments by EG members
Netherlands	For PGM type D and, as applicable, for types B and C, the Power Generating Facility Owner (PGFO) shall hand over to the RSO,: • Results and details of physical tests • Results and details of simulations • Technical data • Statement of compliance • Actual planning of: o Energisation, First Generating Unit (in case of a (O)PPM), 20% of the Maximum Capacity of the (O)PPM, and full capacity o In case of type B or C PGM: Delivery of statement of compliance PGMD o In case of type D PGM: Delivery of statement of compliance EON, ION and FON	N/A

	o Delivery of documents on compliancy tests and simulations o Onsite tests In case of type B or C PGM: From RSO to Power Generating Facility Owner (PGFO) • Reviews of simulations and test results (PGMD) • Declaration of acceptance of the PGMD (RfG Article 32(3)). In case of type D PGM: From the RSO to Power Generating Facility Owner (PGFO) • Reviews of simulations and test results • Energization operational notification (EON) • Interim operational notification (ION) • Final operational notification (FON). https://www.netbeheernederland.nl/_upload/Files/Regulering_20_1d4b9b30b6.pdf	
Poland	Only for Type D, its called "Procedura testowania modułów wytwarzania energii wraz z podziałem obowiązków między właścicielem zakładu wytwarzania energii a operatorem systemu na potrzeby testów"	N/A
Spain	The PGU Owner provides to the TSO/DSO a "PGU Compliance certificate", according to the templates defined in Section 7.1 in NTS. see https://www.ree.es/sites/default/files/01_ACTIVIDADES/Documentos/ProcedimientosOperacion/BOE-A-2019-18275_ministerio_para_la_transicion_ecologica.pdf	N/A
Denmark	No specific templates are available	Provide documentation to show compliance with annex 1, 2 or 3 (dependent on PGM type and technology), which include: testing report, simulation report and manufacturer declaration (when applicable). See guide for connection of power generating plants to the medium and high voltage grid (>1 kV) version 1.1 from October 2021

		Link: https://www.danskenergi.dk/vejledning/nettilslutning/tekniske-regler-produktion Templates used for the for the notification of grid connection of a new generator. Annex connection of power-generating plants to the low-voltage grid (≤1 kV) - Type A and B - Version 1.2 (link) Annex for connection of power-generating plants to the medium and high-voltage grid (>1 kV) - Type B, C - and D - Version 1.1 (link)
Germany	VDE - AR-N 4105, attachment E8 VDE-AR-N 4110, Annex E.11 Commissioning statement for the power generating plant/Storage unit Power-generating system (PGS) certification / Plant certification - Plant Certificate A: standard plant certificate; - Plant Certificate B: simplified plant certificate (only for the connection of power generating plants between PAmax ≥ 135 kW and PAmax ≤ 950 kW to medium-voltage networks); - Plant Certificate C: plant certificate for individual verifications. Manufacture Report, Certificate body report	For the approval, the templates in VDE – AR-N 4105 Annex E would be used. Form E.1 to E.9. Within those, the form E.8 is the commissioning protocol.
Italy	all documents mentioned and listed in the National Standards CEI 0-16 and CEI 0-21.	This includes a declaration of conformity accompanied by a testing report or certificate (PGU)
Romania	technical project, technical data	on site testing, simulations (when required) and certificate
GB	Type certificate if applicable, ENA type registry information or manufacturer declaration and simulation model The PGMDs are contained in G98 and G99.	The PGMDs are contained in G98 and G99, and cover statements of compliance, test reports and simulation reports.

Belgium	No comments	For Synergrid connections, units to be connected need to be homologated based on an analysis specified by the grid operator. Can be based on other certifications (like the German VDE certificate) http://www.synergrid.be/index.cfm?PageID=20872#

Question:

3.5.3 Please describe the Declaration of Conformity by the project developer or Power Generating Facility owner, and any supporting validation documentation

Analysis:

In general, the content of the declaration of conformity will depend on the requirements and templates provided by the relevant member state

The following table shows the summary of all responses:

Table 47 Summary for responses of question 3.5.3

Country	Document Answers by survey participants	Comments by EG members
Netherlands	N/A	N/A
Poland	N/A (documents of conformity are no longer accepted)	N/A
Spain	N/A	N/A
Denmark	N/A	For EON: Protection reports, Harmonic studies, Harmonic model. For ION Compliance studies, RMS and EMT simulation models, Test Plan. For FON Compliance tests, model validation report
Germany	The installer declares that the settings are correct Certificate body report according to TR8	N/A
Italy	N/A	Document containing information specified in "DELIBERAZIONE 13 APRILE 2021 147/2021/R/EEL" from ARERA
Romania	not accepted	N/A

GB	It's a combination of information in the TTR and other information to complete in the PGMD	the PGMD is found in the G99 annex (applicable to the type)
Belgium	N/A	N/A

Question:

3.5.4 Please provide any relevant information for any on-site testing requirements

Analysis:

The onsite testing depends on the Type of unit and the country of installation (some countries don't require testing for smaller PGMs); in some cases, the testing needs to be performed by a third party (authorized testing laboratory).

The following table shows the summary of all responses:

Table 48 Summary for responses of question 3.5.4

Country	Document Answers by survey participants	Comments by EG members
Netherlands	N/A	N/A
Poland	The tests have to be performed by the system operator Follow the document for type D "Procedura testowania modułów wytwarzania energii wraz z podziałem obowiązków między właścicielem zakładu wytwarzania energii a operatorem systemu na potrzeby testów"	N/A
Spain	see chapter 5 of https://aelec.es/wp-content/uploads/2021/07/20210709-NTS-SEPE-v2.1.pdf / https://aeeolica.org/wp-content/uploads/2021/08/Norma-Tcnica-de-Supervisin-SEPE-v2.1_Ingls.pdf	N/A
Denmark	Tests for showing compliance and model validation must be performed.	This test will depend on the Type and are mentioned in the corresponding Annex of the code from Energynet
Germany	e.g. VDE-AR-N 4110, Annex E.11 Commissioning statement for the power generating plant/Storage unit	N/A

	on-site testing is not required	
Italy	N/A	N/A
Romania	tests in connection point as final ones (active, reactive power contril, voltage control)	Testing has to be done according to Order 51 by an authorized third party (Transelectrica can provide possible options)
GB	Annex provides details on-site testing requirements There is nothing apart from G99	N/A
Belgium	N/A	N/A

Question:

3.5.5 Please describe any site specific or generic simulation report (what does it cover? FRT, load flow, reactive power capability, LFSM/FSM, etc)

Analysis:

Simulation reports are needed based on member specific requirements; There is no harmonization on requirements, content or when to require the simulation report. In general, if a certification process is clear, at PGU level, no simulation reports will be needed. At PGM level, some member states ask for simulation reports to check FRT capability and reactive power capability at the PoC in particular.

The following table shows the summary of all responses:

Table 49 Summary for responses of question 3.5.4

Country	Document Answers by survey participants	Comments by EG members
Netherlands	Dependent on the type the report shall contain LFSM-O, LFSM-U, FSM, Blackstar capability, Reactive power capability, Island operation, Fault-Ride-Through, Post Fault active power recovery, Power oscillation damping control, Fast fault current injection, synthetic inertia	From PGU point of view, according to the PGMD, each main requirement needs to be proven by test and/or simulation. This can also be proven by using existing certificates or testing reports as long as the requirement is equal or more stringent.
Poland	N/A	N/A
Spain	N/A	N/A
Denmark	FRT, reactive power capabilities, LFSM/FSM, P-regulation, Q regulation, PF regulation, Voltage regulation, ROCOF, Ramping	Simulation report includes FRT and phase jumps only.
Germany	on-site simulation is not required	N/A

	FGW TR4	
Italy	Any tests or simulations have to be referred to National Standard above mentioned.	N/A
Romania	N/A	
GB	FRT and LFSM-O simulation model and report. For type B requirement are detailed in Annex B4.5 and B4.4 of G99. G99 expects manufacturers to provide generic simulations where these are appropriate.	Simulations for: load flow, LFSM and FRT are required based on type (B onward), see annexes in G99 for details
Belgium	N/A	N/A

Question:

3.5.6 How is a synchronous power generating module defined (total power of plant or individual unit power?)

Analysis:

The definition for SPGM found in the NC RfG defines each SPGU as an SPGM as long as all parts are indivisible. Some member states take the total power at the PoC as the defining power for the SPGM type. This point needs to bel clarified and harmonized at EU level.

The following table shows the summary of all responses:

Table 50 Summary for responses of question 3.5.4

Country	Document Answers by survey participants	Comments by EG members
Netherlands	individual	N/A
Poland	Considered as it is defined in the NC RfG Individual	N/A
Spain	As defined by RfG.	N/A
Denmark	N/A	The grid operator defines the total power at the PoC
Germany	individual unit power	N/A
Italy	The synchronous generators are defined in accordance with established by RfG. (Article 2, point 9, UE Directive 2016/631)	N/A

	Individual units power	
Romania	according RfG	N/A
GB	Currently individual unit power As in the law; an indivisible set of equipment. It is not based on the facility.	N/A
Belgium	N/A	N/A

Question:

3.5.7 How is the boundary for a synchronous power generating module interpreted/fulfilled?

Analysis:

The following table shows the summary of all responses:

Table 51 Summary for responses of question 3.5.4

Country	Document Answers by survey participants	Comments by EG members
Netherlands	indivisible set of installations	N/A
Poland	At the PoC	At the PoC
Spain	The question is not clear.	At the PoC
Denmark	N/A	N/A
Germany	Sync. generators with one control unit or one transformer counts as a single plant alternator terminal and decoupling point	N/A
Italy	It is defined too by RfG. see before point. the italian standard implement the RfG.	N/A
Romania	a SPGM is interpreted in connection point	N/A
GB	An indivisible set of equipment, necessarily including alternators that cannot operate in isolation.	N/A
Belgium	N/A	N/A

Question:

3.5.8 How is the notification of compliance provided? Certificate? Other?

Analysis:

The following table shows the summary of all responses:

Table 52 Summary for responses of question 3.5.4

Country	Document Answers by survey participants	Comments by EG members
Netherlands	test/ simulation reports and registration form (https://www.netbeheernederland.nl /_upload/Files/Regulering_20_a3eb9ede21.pdf)	PGMD with additional simulation and testing reports
Poland	Certificate, and additional testing for Type D	N/A
Spain	the Compliance is provided by a "PGM Compliance certificate" sent to the RSO	N/A
Denmark	EON, ION and FON	PGMD with additional simulation and testing reports, as well as manufacturer declarations
Germany	Certificate, Conformity declaration Discussion with the DSO	Certificate according to applicable VDE (4110, 4120)
Italy	Like said before, by means Declaration of conformity, in accordance with procedures established by National Standard CEI 0-16 and CEI 0-21 implementing the RfG.	Declaration of conformity accompanied by testing report or certificate in case of family
Romania	NFF	Certificate and site testing report
GB	it is provided as certificate or submitted for verification in ENA type registry TTR entry and PGMD	Testing and simulation reports according G99
Belgium	N/A	Homologation list based on other certification processes or documents (Synergrid)

Question:

3.5.9 How is the compliance process enforced? Is it enforced in a robust manner? What is the legal framework for stopping non-compliant equipment from being connected to (or disconnected from) the grid? (Please include any relevant links if possible)

Analysis:

The following table shows the summary of all responses:

Table 53 Summary for responses of question 3.5.4

Country	Document Answers by survey participants	Comments by EG members
Netherlands	The compliance process is dependent on the stages of EON, ION and FON. If a power generating facility is not compliant, the relevant system operator is entitled to refuse power production or to disconnect it.	The PGMD will be key to allow connection. If not accepted, no connection to the grid will be allowed
Poland	Robust, with PTPiREE, see this page: http://ptpiree.pl/opracowania/kodeksy-sieci/warunki-i-procedury	N/A
Spain	The question is not clear.	Provide the relevant certificates at unit and plat level to allow connection
Denmark	EON, ION and FON permits must be applied by the DSO.	Grid operator will check reports to allow connection
Germany	NELEV https://www.gesetze-im-internet.de/nelev/index.html SysSTVO (System-Stabilitätsverordnung	Availability of unit certificate is one of the requirements of the plant level certificate to allow connection
Italy	All equipment not compliant with requirement defined by National Standard implementing RfG are not connectable to the distribution system.	N/A
Romania	a PGM with license cannot be disconnected practically	To obtain the licence, the certificate would be necessary and presented to Transelectrica
GB	Refer to section 15.3 for commissioning test and check required in G99 TTR submissions are reviewed by the ENA, but there is no independent overview of manufacturers' testing.	N/A
Belgium	N/A	Unit to be connected must be in homologation list in Synergrid we page to allow connection

Question:

3.5.10 Is there a time limit to the validity of certificates etc? For connection? For reconnection? For later inspection? For changes?

Analysis:

The following table shows the summary of all responses:

Table 54 Summary for responses of question 3.5.4

Country	Document Answers by survey participants	Comments by EG members
Netherlands	N/A	N/A
Poland	N/A	N/A
Spain	N/A No limits, unless there is a relevant modification in the PGM. Inspection is a part of compliance monitoring after commissioning, so this question is out of context here.	N/A
Denmark	Max 24 month between ION and FON A periodically self-assessment of the compliance of the plant is required.	N/A
Germany	5 years for product certificates (unit, component) No for type A	Yearly updates may be necessary depending on the manufacturer
Italy	No. It is necessary to provide new certification only in case of modification of PGUs or PGMs, like etablished by art. 4 of RfG.	N/A
Romania	No	N/A
GB	no time limit on the validity of certificate unless G99 fundamentally changes/generating unit undergo changes. Refer to section 20 ongoing obligations in G99	N/A
Belgium	N/A	Homologation is based on other documents; when those documents have a limited validity, so will the homologation

1.6 Additional questions

Question:

3.6.1 Is there a monitoring scheme for certificates? If so, please describe it.

Analysis:

There are 15 definite responses, of which 7 provide positive information, the other 8 implying there is no scheme.

Table 55 Summary for responses of question 3.6.1

Country	Information Answers by survey participants	Comments by EG members
Netherlands	N/A	
Poland	N/A	
Spain	It is the responsibility of NTS – assume this means the TSO	
Denmark	No	
Germany	One response implies Yes - see FGW TR8 One response states No.	
Italy	The RSO monitors. It is all described in detail on National Standard CEI 0-16 and CEI 0-21.	
Romania	No – notifications are monitored, but no certificates.	
GB	One response quotes in EREC G99 is quoted. Notes that there is no monitoring scheme.	
Belgium		

Question:

3.6.2 Is there a monitoring scheme for installed Power Generation Modules? If so, please describe it.

Analysis:

There are 15 definite responses, of which 8 provide positive information.

Table 56 Summary for responses of question 3.6.2

Country	Document Answers by survey participants	Comments by EG members

Netherlands	Scheme to be agreed between the generation owner and the relevant system operator – this is possibly a misapprehension of the question.	
Poland	N/A	
Spain	Yes – the reference given is Title IV of the RfG	
Denmark	Respondent states there is no scheme	
Germany	There is the Marktstammdatenregister (Market data register)	
Italy	No scheme – all certifications are checked individually	
Romania	Yes – but based on the behaviour in the grid – assume during disturbances, although no detail is provided.	
GB	The approach in EREC G99 is quoted. Notes that there is no monitoring scheme.	
Belgium		

<u>Question:</u>

3.6.3 Is there a scheme for prototype status? What is the legal status? How is testing carried out at test institutions?

<u>Analysis:</u>

There 13 definite responses, of which 6 provide positive information.

Table 57 Summary for responses of question 3.6.3

Country	Document Answers by survey participants	Comments by EG members
Netherlands	There is a scheme that allows operation for up to two years. Independent certification is required.	
Poland		
Spain	No	
Denmark	No	
Germany	Prototype confirmation as per VDE-AR-N 4110/4120/4130 A separate submission does not quote the standard, but states that certification only relies on manufacturer's declaration.	

	The declaration is valid for 2 years. A protection certificate is mandatory	
Italy		
Romania	Cites the emerging technology section of the RfG – so this is probably a misapprehension of the RfG.	
GB	Confirmation there is no scheme.	
Belgium		

Annex II: Detailed analysis of requirements at unit terminals

This chapter presents the analysis performed by the subgroup for Type A, B and C requirements

1.1 Detailed analysis of Type A requirements (RfG, Article 13, "General requirements for type A power-generating modules")

1. Type A power-generating modules shall fulfil the following requirements…:

(a) With regard to frequency ranges:

(i) a power-generating module shall be capable of remaining connected to the network and operate within the frequency ranges and time periods specified in Table 2;

(ii) …

(iii) ….

(b) …a power-generating module shall be capable of staying connected to the network and operate at rates of change of frequency up to a value specified by the relevant TSO, unless disconnection was triggered by rate-of-change-of-frequency-type loss of mains protection. ….

COMMENT - *This requirement, like others involving frequency, is not directly referred to PoC or to PGU terminals, as frequency is the same in both points (and all over the network).*

PROPOSAL - *Regard the requirement as referred to PGU terminals.*

2. With regard to the limited frequency sensitive mode — overfrequency (LFSM-O), the following shall apply…:

(a) the power-generating module shall be capable of activating...active power frequency response according to figure 1 at a frequency threshold and droop settings specified by the relevant TSO;

(b) instead of…paragraph (a), the relevant TSO may choose to allow…automatic disconnection and reconnection of power-generating modules of Type A at randomised frequencies…above a frequency threshold, …where it is able to demonstrate…that this has a limited cross-border impact and maintains the same…operational security…;

(c) the frequency threshold shall be between 50,2 Hz and 50,5 Hz inclusive;

(d) the droop settings shall be between 2 % and 12 %;

(e) the power-generating module shall be capable of activating a power frequency response with an initial delay that is as short as possible. If that delay is greater than two seconds, the power-generating facility owner shall justify the delay…;

(f) the relevant TSO may require that upon reaching minimum regulating level, the power-generating module be capable of either:

(i) continuing operation at this level; or

(ii) further decreasing active power output;

(g) …When LFSM-O is active, the LFSM-O setpoint will prevail over any other active power setpoints.

COMMENT - *This requirement is not directly referred to PoC or to PGU terminals, as frequency is the same in both points, and power output does not depend on any given point, but only on the PGU.*

PROPOSAL-*Regard the requirement as referred to PGU terminals.*

3. The power-generating module shall be capable of maintaining constant output…regardless of changes in frequency, except where output follows the changes specified in the context of paragraphs 2 and 4 of this Article or points (c) and (d) of Article 15(2) as applicable.

COMMENT - *This requirement is not directly referred to PoC or to PGU terminals, as frequency is the same in both points, and power output does not depend on any given point, but only on the PGU.*

PROPOSAL- *Regard the requirement as referred to PGU terminals.*

4. The relevant TSO shall specify admissible active power reduction …with falling frequency…as a rate of reduction falling within the boundaries, illustrated by the full lines in Figure 2:

below 49 Hz falling by a reduction rate of 2 % of the maximum capacity at 50 Hz per 1 Hz frequency drop;

(b) below 49,5 Hz falling by a reduction rate of 10 % of the maximum capacity at 50 Hz per 1 Hz frequency drop.

COMMENT - *This requirement is not directly referred to PoC or to PGU terminals, as frequency is the same in both points, and the percentage change in power output does not depend on any given point, but only on the PGU.*

PROPOSAL-*Regard the requirement as referred to PGU terminals.*

6. The power-generating module shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received at the input port. The relevant system operator shall have the right to specify requirements for equipment to make this facility operable remotely.

COMMENT - *This requirement is not directly referred to PoC or to PGU terminals, as power output does not depend on any given point, but only on the PGU.*

PROPOSAL-*Regard the requirement as referred to PGU terminals.*

7. The relevant TSO shall specify the conditions under which a power-generating module is capable of connecting automatically to the network. Those conditions shall include:

(a) frequency ranges within which an automatic connection is admissible, and a corresponding delay time; and

(b) maximum admissible gradient of increase in active power output.

Automatic connection is allowed unless specified otherwise….

COMMENT - *This requirement is not directly referred to PoC or to PGU terminals, as frequency is the same in both points, and power output gradient does not depend on any given point, but only on the PGU.*

PROPOSAL-*Regard the requirement as referred to PGU terminals.*

1.2 Detailed analysis of Type B requirements (RfG, Article 14, “General requirements for type B power-generating modules”)

1. Type B power-generating modules shall fulfil the requirements set out in Article 13, except for Article 13(2)(b).

…

3. Type B power-generating modules shall fulfil the following requirements in relation to robustness:

(i) each TSO shall specify a voltage-against-time-profile…at the connection point…, which describes the conditions in which the power-generating module is capable of staying connected to the network and continuing to operate stably…;

…(vi) the power-generating module shall be capable of remaining connected to the network and continuing to operate stably when…the phase-to-phase voltages…at the connection point during a symmetrical fault…remain above the lower limit…

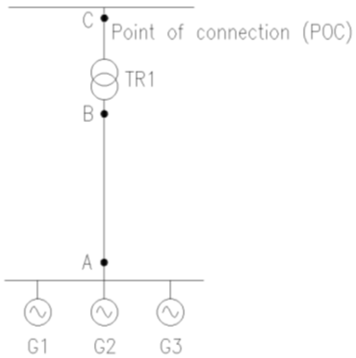
COMMENT - *This requirement is referred to PoC; however, if the PGU is capable of withstanding a given voltage-against-time-profile at PGU terminals, it is also capable to withstand that same profile at PoC.*

PROPOSAL-*Regard the requirement as referred to PGU terminals.*

d)…:power-generating facilities shall be capable of exchanging information with the relevant system operator or the relevant TSO in real time or periodically with time stamping…;

COMMENT - This requirement is not referred to PoC or to PGU terminals, but only on the PGU.

1.3 Detailed analysis of Type C requirements (RfG, Article 15, "General requirements for type C power-generating modules")



2….:(a)…the power-generating module control system shall be capable of adjusting an active power setpoint…

COMMENT- It does not matter what the losses are between PGU terminals (point A in figure) and PoC (point C in figure); there is still modulation of the active power at the connexion point – it is just numerically different to that at the generating unit terminals, but the RfG does not require it to be the same.

PROPOSAL- Refer this requirement to PGU terminals (point A in the figure) rather than PoC (point C in the figure).

2 (c)…(i) the power-generating module shall be capable of activating the provision of active power frequency response at a frequency threshold and with a droop specified by the relevant TSO…

COMMENT – Active power output, frequency threshold and droop are all relevant to the PGU, and not to any specific network point.

PROPOSAL- Refer this requirement to PGU terminals (point A in the figure) rather than PoC (point C in the figure).

2 …(d) in addition to point (c)…, the following shall apply cumulatively when frequency sensitive mode ('FSM') is operating:

the power-generating module shall be capable of providing active power frequency response in accordance with the parameters specified by each…TSO within the ranges shown in Table 4.…

Table 58 This is Table 4 as specified in the NC RfG - Parameters for active power frequency response in FSM

Parameters	Ranges
Active power range related to maximum capacity (ΔP1/Pmax)	1,5-10 %
Frequency response insensitivity	10-30 mHz (0,02-0,06 %)
Frequency response deadband	0-500 mHz
Droop s1	2-12 %

COMMENT – *Active power range, frequency insensitivity, frequency deadband and droop are all relevant to the PGU, and not to any specific network point.*

PROPOSAL- *Refer this requirement to PGU terminals (point A in the figure) rather than PoC (point C in the figure).*

(iii) in the event of a frequency step change, the power-generating module shall be capable of activating full active power frequency response, at or above the full line shown in Figure 6…

COMMENT – *Power frequency response is relevant to the PGU, and not to any specific network point.*

PROPOSAL- *Refer this requirement to PGU terminals (point A in the figure) rather than PoC (point C in the figure).*

…(v) the power-generating module shall be capable of providing…frequency response for a period of between 15 and 30 minutes.…

4…: (a) in the event of power oscillations, power-generating modules shall retain steady-state stability when operating at any operating point of the P-Q-capability diagram;

COMMENT - *Reactive power can be tested at the factory to give out a PGU certificate where the CONTROL and CAPABILITY for reactive power of the unit can be stated. This capacity can then be used to do a site analysis (for example, simulation study) and provide the PGM certificate. The PGU certificate would guarantee to the customer (and grid operator) that the correct functions are available and the data provided (PQ diagram for example) is certified.*

PROPOSAL- *Refer this requirement to PGU terminals (point A in the figure) rather than PoC (point C in the figure).*

4…: (b)…power-generating modules shall be capable of remaining connected to the network and operating without power reduction, as long as voltage and frequency remain within the specified limits…;

COMMENT-*If the voltage requirement is fulfilled at PGU terminals (point A in the figure), it is also fulfilled at PoC (point C in the figure): point A compliance is a sufficient condition for point C compliance.*

PROPOSAL- *Refer this requirement to PGU terminals (point A in the figure) rather than PoC (point C in the figure).*