GRID CODE COMPLIANCE IN EUROPE
WAYS TO A FAST AND SAFE GRID CONNECTION

Bernd Hinzer
Markus Holzapfel
AGENDA

► GRID CODE COMPLIANCE (GCC) – AN OVERVIEW
► NETWORK CODE (NC) REQUIREMENTS FOR GENERATORS (RFG)
► IMPLEMENTATION OF NC RFG ON THE NATIONAL LEVEL
► A COMPARISON BETWEEN GERMANY, POLAND, SPAIN AND THE NETHERLANDS
► GRID CONNECTION REQUIREMENTS AND VERIFICATION - AN APPROACH TO LOWER RISKS
► EXAMPLE MARKET REQUIREMENTS
► FINAL NOTES
WHY GRID CODE COMPLIANCE (GCC)?

Grid Code Compliance (GCC) means “the tasks related to assessment, verification and certification of technical performance capabilities required in grid codes and similar documents. Similar documents could be laws dealing with power purchase agreements or conditions related to grid connection. Also testing, simulating and evaluating of any electrical impact on the electrical systems for distribution and transmission of electrical energy can be part of GCC.”

• To get connected a renewable generation project, several projects steps and proofs have to be carried out
• The final „Go“, including first time operating parallel to the grid, needs a defined quality, documentation, communication and behaviour of the project, to be provided in parallel / ahead the commissioning!
• What does it mean for projects in European grid, to be compliant to grid connection requirements?
• Who cares?
TYPES OF COMPLIANCE VERIFICATION

Verification means “confirmation, through the provision of objective evidence, that specified requirements have been fulfilled.”
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NC RFG BECAME EU REGULATION (2016/631)

- RfG provides a **common set of requirements** and an **overall structure** for **compliance assessment**
- As an EU regulation, the RfG is directly enforced in every member country
- Its Implementation is **strongly customized** by each member country

**Targets**
- Establish legally binding **pan-European harmonization** of grid connection requirements
- Ensure **system security** with a growing share of intermittent renewable energy generation

**DETERMINATION OF SIGNIFICANCE / GENERATOR TYPES**

- Requirements technology neutral according to **system significance** of the generators, depending on:
  - **Maximum capacity** of the generator
  - **Voltage level** at grid connection point

<table>
<thead>
<tr>
<th>Type</th>
<th>Requirements</th>
<th>Capacity (Cont. Europe)</th>
<th>Voltage level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type D</td>
<td>Wide-scale network operation and stability&lt;br&gt;• Balancing services</td>
<td>&gt; 75 MW</td>
<td>≥ 110 kV</td>
</tr>
<tr>
<td>Type C</td>
<td>Stable and controllable dynamic response&lt;br&gt;• Covering all operational network states</td>
<td>&gt; 50 MW</td>
<td>&lt; 110 kV</td>
</tr>
<tr>
<td>Type B</td>
<td>Automated dynamic response, resilience to events&lt;br&gt;• System operator control</td>
<td>&gt; 1 MW</td>
<td>&lt; 110 kV</td>
</tr>
<tr>
<td>Type A</td>
<td>Basic capabilities to withstand wide-scale events&lt;br&gt;• Limited automated response and control</td>
<td>&gt; 0.8 kW</td>
<td>&lt; 110 kV</td>
</tr>
</tbody>
</table>

Grid Codes in Europe - Overview on the current requirements in European codes and national interconnection standards, Roland Bründlinger, AIT Austrian Institute of Technology

*Image of the page with text and table.*
## REQUIREMENTS – FREQUENCY STABILITY (PPM)

<table>
<thead>
<tr>
<th>RfG Article</th>
<th>Requirement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>13(1)(a)</td>
<td>Frequency range</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>13(2)</td>
<td>Limited Frequency Sensitive Mode – Overfrequency (LFSM-O)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>13(1)(b)</td>
<td>Rate of Change of Frequency (RoCoF) withstand capability</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>13(3)</td>
<td>Constant output at target active power</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>13(4)</td>
<td>Maximum power reduction at underfrequency</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>13(7)</td>
<td>Automatic connection</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>15(2)(a)</td>
<td>Active power controllability and control range</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15(2)(d)</td>
<td>Frequency Sensitive Mode (FSM)</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15(2)(e)</td>
<td>Frequency Restoration Control</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15(2)(c)</td>
<td>Limited Frequency Sensitive Mode – Underfrequency (LFSM-U)</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15(2)(g)</td>
<td>Monitoring of frequency response</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# REQUIREMENTS – VOLTAGE STABILITY (PPM)

<table>
<thead>
<tr>
<th>RfG Article</th>
<th>Requirement</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>16(2)</td>
<td>Voltage range</td>
<td></td>
<td></td>
<td></td>
<td>●</td>
</tr>
<tr>
<td>20(2)(a)</td>
<td>Reactive power capability (simple)</td>
<td></td>
<td></td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>20(2)(b)</td>
<td>Fast fault current injection</td>
<td></td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>21(3)(b)</td>
<td>Reactive power capability at maximum capacity (U-Q/P_{max}-profile)</td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>21(3)(c)</td>
<td>Reactive power capability below maximum capacity (P-Q/P_{max}-profile)</td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>21(3)(d)</td>
<td>Reactive power control modes</td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
<tr>
<td>21(3)(f)</td>
<td>Power Oscillation Damping (POD) control</td>
<td></td>
<td>●</td>
<td>●</td>
<td></td>
</tr>
</tbody>
</table>
“… power generating module document’ or ‘PGMD’ means a document provided by the power generating facility owner to the relevant system operator for a type B or C power generating module which confirms that the power generating module’s compliance with the technical criteria set out in this Regulation has been demonstrated and provides the necessary data and statements, including a statement of compliance …”

“ …Member States may provide that the PGMD shall be issued by an authorised certifier …”

ENTSO-E guidance document for national implementation for network codes on grid connection (March 2017, already under re-construction), providing guidance on

• Compliance Testing (CT)
• Compliance Simulation (CS)
• Compliance Monitoring (CM)

ENTSO-E publishes occasional updates for each country for the implementation of the RfG and the other connection codes (https://www.entsoe.eu/active-library/codes/cnc/)
RESPONSIBILITIES

Grid operator’s responsibility
“It is the responsibility of the relevant system operator (RSO) to assess the compliance of a power-generating module with the requirements applicable under this Regulation, throughout the lifetime of the power-generating facility.”

Owner’s responsibility
“It is the responsibility of the power-generating facility owner to ensure compliance throughout the lifetime of their equipment. The Power-Generating Facility Owner may rely upon equipment certificates.”
“…carrying out the tests in accordance with the conditions laid down in Chapters 2, 3 and 4 of RfG Title IV.”
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DEFINITION OF CAPACITY THRESHOLDS

<table>
<thead>
<tr>
<th>Synchronous areas</th>
<th>Max threshold type B</th>
<th>Max threshold type C</th>
<th>Max threshold type D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continental Europe</td>
<td>1 MW</td>
<td>50 MW</td>
<td>75 MW or &gt; 110 kV</td>
</tr>
<tr>
<td>Great Britain</td>
<td>1 MW</td>
<td>50 MW</td>
<td>75 MW or &gt; 110 kV</td>
</tr>
<tr>
<td>Nordic</td>
<td>1.5 MW</td>
<td>10 MW</td>
<td>30 MW or &gt; 110 kV</td>
</tr>
<tr>
<td>Ireland and Northern Ireland</td>
<td>0.1 MW</td>
<td>5 MW</td>
<td>10 MW or &gt; 110 kV</td>
</tr>
<tr>
<td>Baltic</td>
<td>0.5 MW</td>
<td>10 MW</td>
<td>15 MW or &gt; 110 kV</td>
</tr>
</tbody>
</table>

**GERMANY**

- **TYPE A:** \(0.8\ kW \leq P_{\text{MAX}} < 135\ kW**
- **TYPE B:** \(135\ kW \leq P_{\text{MAX}} < 36\ MW**
- **TYPE C:** \(36\ MW \leq P_{\text{MAX}} < 45\ MW**
- **TYPE D:** \(P_{\text{MAX}} \geq 45\ MW**
RfG also stipulates minimum requirements for compliance assessment

**Latest example: Poland**
- Publication: 20/03/2020
- Valid from: 01/07/2020

<table>
<thead>
<tr>
<th>Features</th>
<th>Rules for using equipment or component certificates (C) for PPM or perform alternatively compliance tests (T) and/or simulations (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>RfG article</strong></td>
</tr>
<tr>
<td>LFSM-O</td>
<td>13(2)</td>
</tr>
<tr>
<td>LFSM-U</td>
<td>15(2)(c)</td>
</tr>
<tr>
<td>FSM</td>
<td>15(2)(d)</td>
</tr>
<tr>
<td>Frequency restoration</td>
<td>15(2)(e)</td>
</tr>
<tr>
<td>Active power controllability</td>
<td>15(2)(a)</td>
</tr>
<tr>
<td>Voltage control mode</td>
<td>21(3)(d)</td>
</tr>
<tr>
<td>Reactive power control mode</td>
<td>21(3)(d)</td>
</tr>
<tr>
<td>Power factor control mode</td>
<td>21(3)(d)</td>
</tr>
<tr>
<td>Fast fault current injection</td>
<td>20(2)(b)</td>
</tr>
<tr>
<td>Fault-ride through (FRT)</td>
<td>14(3)(a) / 16(3)</td>
</tr>
<tr>
<td>Post-fault active power recovery</td>
<td>20(3)</td>
</tr>
<tr>
<td>Island operation</td>
<td>15(5)(b)</td>
</tr>
<tr>
<td>Reactive power capability</td>
<td>21(3)(b)(c)</td>
</tr>
</tbody>
</table>

PTPIREE ‘Warunki i procedury wykorzystania certyfikatów w procesie przyłączenia modułów wytwarzania energii do sieci elektroenergetycznych’, 01/07/2020
OVERVIEW BY COUNTRIES

compliance by certification vs. compliance by testing and simulation

• Compliance by certification via project certificate only in Germany (since 10 years) and Spain until now (Poland and the Netherlands are discussing about)

• But: Equipment certificates mostly to be issued by ISO/IEC 17065 accredited certification bodies as proof of compliance for specific capabilities accepted in many countries

• Supplementary compliance testing still very common

• Compliance simulations either performed by certification bodies or service providers (without accreditation)
KEEPPING TRACK OF NATIONAL IMPLEMENTATIONS

- **National implementations** of the RfG mostly approved
- But: High level of **uncertainty regarding the application** of the updated **Grid Codes**
- National **compliance verification procedures** (certification schemes, guidelines for compliance testing / simulations) **still in progress** (e.g. NL and ES)
- ENTSO-E offers valuable information (e.g. Implementation Guidance Documents (IGD’s))
  Link to CNC Active Library: [https://www.entsoe.eu/active-library/codes/cnc/](https://www.entsoe.eu/active-library/codes/cnc/)
KEEPING TRACK OF NATIONAL IMPLEMENTATIONS

Challenges for the manufacturer's
• Highest possible standardization (maintaining the conformity of certified functions)
• Greatest possible flexibility with regard to grid support functions (tailor-made solution for many markets)

Challenges for international active advisor, operator and commissioner
• Being permanent online regards the new/upcoming national regulations about proof at project level
• Does the planning fit the grid?
• How to receive a summary of relevant expectations to be fulfilled?
YOUR ROAD TO A FAST AND SAFE GRID CONNECTION

**Definition**
- Pre-screening
  - Technical investigation of GCC requirements and/or certification rules in market(s) of interest

  → Define assessment scope

**Verification**
- • Basic documentation
  - • Preparing test plan / procedure
  - • Verification tests
  - • Simulation plan / procedure
  - • Preparing simulation model
  - • Model validation
  - • Reporting

**Certification**
- Compliance Assessment
  - Issuing a certificate / SoC
    - • Component certificate (CC),
    - • Equipment certificate (EC),
    - • Type certificate (TC),
    - • Project certificate (PC),
    - • Statement of compliance (SoC)

- Compliance monitoring
  - • Revision of certificate or SoC
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**GERMAN IMPLEMENTATION**

**LAW**
- **ENTSO-E RfG**
- **NELEV** Ordinance to proof electrical behaviour of generators at grid
- **EEG / EnWG** Renewable Energy Sources Act

**TECHNICAL GUIDELINES**
- **Technical Connection Rules for low voltage, medium voltage & high voltage**
  - VDE-AR-N 4100 (connection LV grid)
  - VDE-AR-N 4110 (connection MV grid)
  - VDE-AR-N 4120 (connection HV grid)
  - VDE-AR-N 4105 (generators LV grid)
  - VDE-AR-N 4130 (connection extHV grid)

- **FGW Technical guidelines for testing, simulations & certification**
  - TG3
  - TG4
  - TG8

- **DIN EN ISO/IEC 17065**
A COMPARISON BETWEEN GERMANY, POLAND, SPAIN AND THE NETHERLANDS

POLISH IMPLEMENTATION

<table>
<thead>
<tr>
<th>Requirement</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
<tr>
<td>Certification Type</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>RequiredTest</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>B</td>
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<tr>
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<tr>
<td>Certification Type</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>B</td>
<td>C</td>
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<tr>
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<td>Certification Type</td>
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<td>B</td>
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<td>D</td>
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<td>Certification Type</td>
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<td>C</td>
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<td>Not applicable</td>
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• Since 20th March 2020 a new technical guideline is available which is targeting the national certification approach

• Type / component / equipment certification

• Certificates can be replaced transitionally by compliance tests and/or simulations

• Project certification approach still under negotiation

• Transitional period: 27 April 2019 to 27 April 2021
**Spanish Implementation**

**LAW**

- **ENTSO-E**
- **RfG**
  - RD 647/2020: Royal Decree establishing the application of the NTS with regard to compliance (RfG, Title IV)
  - Orden ministerial (OM): Ministry of Industry, Trade and Tourism (MINETUR)

**TECHNICAL GUIDELINES**

- **Type A**
  - (0.8 kW ≤ P<sub>max</sub> ≤ 100 kW)
- **Type B**
  - (100 kW < P<sub>max</sub> ≤ 5 MW)
- **Type C**
  - (5 MW < P<sub>max</sub> ≤ 50 MW)
- **Type D**
  - (P<sub>max</sub> > 50 MW)

**PO 12.2**

**REE / AELEC Technical guideline for testing, simulations & certification**

**NTS**

**DIN EN ISO/IEC 17065**
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DUTCH IMPLEMENTATION

ENTSO-E
RfG

ACM Decisions
Netherlands Authority for Consumers and Markets (ACM)

Electricity Act 1998
Ministry of Economic Affairs and Climate (EZK)

LAW

TECHNICAL GUIDELINES

Type A
(0.8 kW ≤ P_{max} < 1 MW)

Type B
(1 MW ≤ P_{max} < 50 MW)

Type C
(50 MW ≤ P_{max} < 60 MW)

Type D
(P_{max} ≥ 60 MW)

Netcode elektriciteit
(‘Dutch Grid Code’, last updated: June 2020)

Netbeheer Nederland’s guideline for testing, simulations & certification

RfG compliance verification
(Compliance Verification Procedure)
ZONNEPARK MIDDEN-GRONINGEN - NL

Example compliance verification (before RfG!)

- Extensive on-site compliance testing
  - Active power controllability
  - LFSM-O (inverter or plant level)
  - Reactive power control modes (U, Q, cos ϕ)
  - Power Quality (PQ)
- New testing approach for type D PPM even more extensive (e.g. 4-hour Q capability test)

But, please note!
According to RfG, Article 48 (10) only one reactive power control mode needs to be tested!
SIMULATION MODELS

Germany
• Validated (FGW TG4) simulation model for unit (PV inverter) and component (PPC)
• No preference with regard to software (PowerFactory, MATLAB/Simulink, etc.)
• Supplementary compliance simulations by accredited certification body

Netherlands
• Detailed and aggregated model (PowerFactory & PSS/E)
• ‘Preliminary’ and ‘As-built’ model (validation: IEC 61400-27-2)

Spain
• ‘NTS model’ (e.g. PowerFactory or similar) and ‘PO 9 model’ (PSS/E mandatory) for PV inverter and PPC
• Supplementary compliance simulations by accredited (EN ISO/IEC 17065) certification body
WHERE ARE WE, WHERE DO WE NEED TO GO

• Although the requirements (RfG + national implementations of non-exhaustive requirements are in place) – we lack joint guidelines for compliance assessment.
  • Upcoming
    • IECRE for certification (relying on existing IEC standards for testing and simulations)
    • EN 50549-1/-2 for testing (B, C) & -10 for certification
  • Meanwhile existing
    • DNVGL-ST-0125 (standard)
    • DNVGL-SE-0124 (service specification)

• Creating a joint framework and terminology for European grid codes is an important step.
  • But it will be a bit of a puzzle for yet another while.

• Next step: Harmonizing also compliance assessment.

Available for free (just google it)!
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WHEN DOES GRID CODE COMPLIANCE START?

**Project planning phase**
- Project studies and pre-screening
- GCC component and type certification

**Project realization phase**
- Project pre-assessment
- GCC project certificate

**Commissioning phase**
- Declaration of conformity

**Operation phase**
- Recurring declaration of conformity
POWER PLANT CONTROLLER (PPC) – ONLY A PRODUCT?

Scope of functionality
(Pre-screening)
- Active power management
- Solar power trading interface
- Reactive power management
- Real-time process data exchange

GCC services
- Project consulting
- Controller tuning
- Test procedure
- Simulation models (project-specific)

GCC services
- Site Acceptance Testing (SAT)
- Test report
- Model validation (project-specific)

Service & O&M
- PPC monitoring
- KPI's (e.g. PR)
- Remote service access
- Diagnosis options (remote / local)

Planning → Realization → Commissioning → Operation
THE IMPORTANCE OF SUCCESS CRITERIA

Control dynamics
- Rise time
- Settling time

\[ T_{\text{rise} \ 90\% \ \Delta Q} = 2.05 \text{ s} \ (\leq 2.5 \text{ s}) \]
\[ T_{\text{settling} \ \Delta Q} = 5.50 \text{ s} \ (\leq 7.0 \text{ s}) \]
Overshoot

\[ \Delta Q_{\text{max}} = 4.9 \text{ Mvar} \ (16.7 \% \text{ step size}) \]

VDE-AR-N 4120 (TCR HV)

\[ \Delta Q_{\text{max}} = (25\% \times (2 \text{ s} / T_{\text{rise} \ 90\% \Delta Q}) + 5\% = (25\% \times (2 \text{ s} / 2.5 \text{ s}) + 5\% = 25\% \]
THE IMPORTANCE OF SUCCESS CRITERIA

**Static grid support**
Possibilities to take into account:
- Reactive compensation
- Fix reduction at generator
- Flex reduction via *farm controller*

➡️ Active / reactive farm control

**Power loss and limitations**
A question of component dimensioning

**Grid interferences**
A question of generator, if it fits the grid (not each type-certified generator fit each project!)

**Dynamic behaviour**
Does the last generator in large farms recognize, that there is a grid fault to react on?
Does the generator can provide the expected grid support during fault (Q-support)?

**Protection setup**
Does the setup runs sufficient in fault and grid supporting phase (does the protection trip?)
THE IMPORTANCE OF SUCCESS CRITERIA

Load vs. Generation at PCC
If genset is managed in partial load, the load is pushing the power factor out of allowed range!

A challenge for the farm controller!
COMPLIANT GRID CONNECTION

Final Operational Notification (FON) means “a notification issued by the relevant system operator to a power-generating facility owner […] who complies with the relevant specifications and requirements, allowing them to operate respectively a power-generating module […] by using the grid connection.”

- FON in Germany: Declaration of conformity
- Compliance monitoring (see RfG, Article 40) requires that after granting FON, the PPM (PV plant) owner shall:
  - Ensure compliance throughout the lifetime of the PPM
  - Inform the grid operator about any planned modification of the PPM (if compliance is affected)
  - Inform the grid operator about any operational incidents / failures of the PPM (if compliance is affected)
AGENDA

► GRID CODE COMPLIANCE (GCC) – AN OVERVIEW
► NETWORK CODE (NC) REQUIREMENTS FOR GENERATORS (RFG)
► IMPLEMENTATION OF NC RFG ON THE NATIONAL LEVEL
► A COMPARISON BETWEEN GERMANY, POLAND, SPAIN AND THE NETHERLANDS
► GRID CONNECTION REQUIREMENTS AND VERIFICATION - AN APPROACH TO LOWER RISKS
► EXAMPLE MARKET REQUIREMENTS
► FINAL NOTES
EXAMPLE MARKET REQUIREMENTS

GERMANY

Keywords:
- Prototypenbescheinigung
- Einheiten- / Komponentenzertifikat
- Anlagenzertifikat (A / B)
- EZA-Konformitätserklärung

Legal / normative basis:

✓ Requirements
  - LFSM-O (Inverter capability!)
  - P control (with ramp rate limiting)
  - Q (U), Q (P), Q fix, cos φ fix
  - …

✓ Compliance
  - Unit / component certificate
  - Compliance testing (.only‘ supplementary)
  - Compliance simulations (carried by the certification body)

✓ Verification
  - Project certification acc. to FGW TG8
NETHERLANDS

Keywords:
• Aansluit- en Transportovereenkomst (ATO), connection agreement
• Preliminary / As-built model

Legal / normative / guideline basis:
• Netbeheer Nederland ‘Netcode elektriciteit’, text as from 1 January 2020, last updated on 2020-02-11 (including ACM proposals), 01/01/2020

Requirements
▪ LFSM-O \( (T_{settling} \Delta P = 20 \text{ s}) \)
▪ \( P \) control
▪ \( V \) control (V1- & V2-mode), \( Q \) control, \( \cos \phi \) control
▪ …

Compliance
▪ Equipment certificate (possible)
▪ Compliance testing
▪ Compliance simulations
▪ PowerFactory simulation model
▪ PSS/E simulation model

Verification
▪ Project certification acc. to Compliance verification procedure
AGENDA

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► FINAL NOTES
BRIEF INFORMATION

- Grid Code Compliance (GCC) means providing **technical functionality** and **assessment / verification**
- GCC is offering a **safe and reliable reporting** for each stakeholder expecting high quality & trust in investment
- For some countries (e.g. Germany and Spain) **equipment certificates** for the PPC are mandatory
- For some countries (e.g. Netherlands) **compliance testing & simulations** for the entire PPM is mandatory
- **Simulation models** (e.g. PowerFactory, PSS/E) are required for system studies (compliance simulations)
- Accurate **controller tuning** is key in order to comply with required **control dynamics** (e.g. $T_{\text{rise}} = 2.5$ s)
- Dynamics of the **PV inverter** significantly affects the overall control dynamics (rise time, settling time) (Observe the settling time and ramp rates in the equipment certificate (unit certificate) of the inverter type!)
- If **no specific requirements** on compliance testing are known, a **test procedure** is strongly recommended!

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BACKUP
GERMAN IMPLEMENTATION
Demand of certification starting from 135kW at PCC.

- **> 950 kW**
  - Project Certificate Type A

- **135 – 950 kW**
  - Project Certificate Type B

- **Generator without type/equipment certificate**
  - Project Certificate Type C

**Expertise of international operating service provider**
- at measurement (DIN EN ISO 17025)
- at evaluation and at certification (DIN EN ISO 17065)

**Steps of Certification**
- Component-and Type Certificate
- Project planning (independent to Certification body)
- Project Certificate
- Commissioning declaration
- Declaration of Conformity
EXAMPLE MARKET REQUIREMENTS

SPAIN

Keywords:
- Certificado de equipo
- Certificado final de MGE
- Validación de ensayos / de modelos

Legal / normative / guideline basis:
- NTS v1.0, ‘Norma Técnica de Supervisión de la conformidad de los módulos de generación de electricidad según el Reglamento UE 2016/631 (v1.0), 18/07/2019
- P.O. 9.0 ‘Información intercambiada por el operador del sistema’
- P.O. 12.2 ‘Instalaciones conectadas a la red de transporte: requisitos mínimos de diseño, equipamiento, funcionamiento y seguridad y puesta en servicio

Requirements
- LFSM-O
- P control
- V control, Q control, cos φ control
- …

Compliance
- Equipment certificate for PPC
- No project-specific compliance testing required
- PowerFactory simulation model
- PSS/E simulation model

Verification
- Project certification acc. to NTS v1.0
EXAMPLE MARKET REQUIREMENTS

UNITED KINGDOM

Keywords:
• Power Generating Module (PGM)
• Power Park Module (PPM)
• Power Generating Facility (PGF)

Legal / normative basis:
• Energy Networks Association (ENA) Engineering Recommendation (ERE) G99 ‘Requirements for the connection of generation equipment in parallel with public distribution networks on or after 27 April 2019’, 09/03/2020

✓ Requirements
  ▪ LFSM-O
  ▪ P control \( T_{settling \Delta P} = 5 \text{ s} \)
  ▪ V control, Q control, cos \( \phi \) control
  ▪ …

✓ Compliance
  ▪ Equipment certificate (tbc)
  ▪ Compliance testing
  ▪ Compliance simulations

✓ Verification
  ▪ Compliance testing mandatory (G99, Annex B.6, C.9)
  ▪ Compliance simulation mandatory (G99, Annex B.4, C.7)
**EXAMPLE MARKET REQUIREMENTS**

**POLAND**

**Keywords:**
- Certyfikat jednostki
- Certyfikat komponentu
- Test polowy (field test)

**Legal / normative / guideline basis:**
- PSE S.A. ‘Wymogi ogólnego stosowania wynikające z Rozporządzenia Komisji (UE) 2016/631 z dnia 14 kwietnia 2016 r. ustanawiającego kodeks sieci dotyczący wymogów w zakresie przyłączenia jednostek wytwórczych do sieci (NC RfG)’, 18/12/2018
- PTPiREE ‘Warunki i procedury wykorzystania certyfikatów w procesie przyłączenia modułów wytwarzania energii do sieci elektroenergetycznych’, 20/03/2020

**✓ Requirements**
- LFSM-O
- P control
- V control ($T_{rise} = 5$ s, $T_{settling} = 60$ s)
- Q control, cos $\varphi$ control
- ...

**✓ Compliance**
- Equipment certificate
- Compliance testing
- Compliance simulations (optional)

**✓ Verification**
- Transitional provision from 27/04/2019 to 27/04/2021
- Compliance testing / simulations instead of certificates