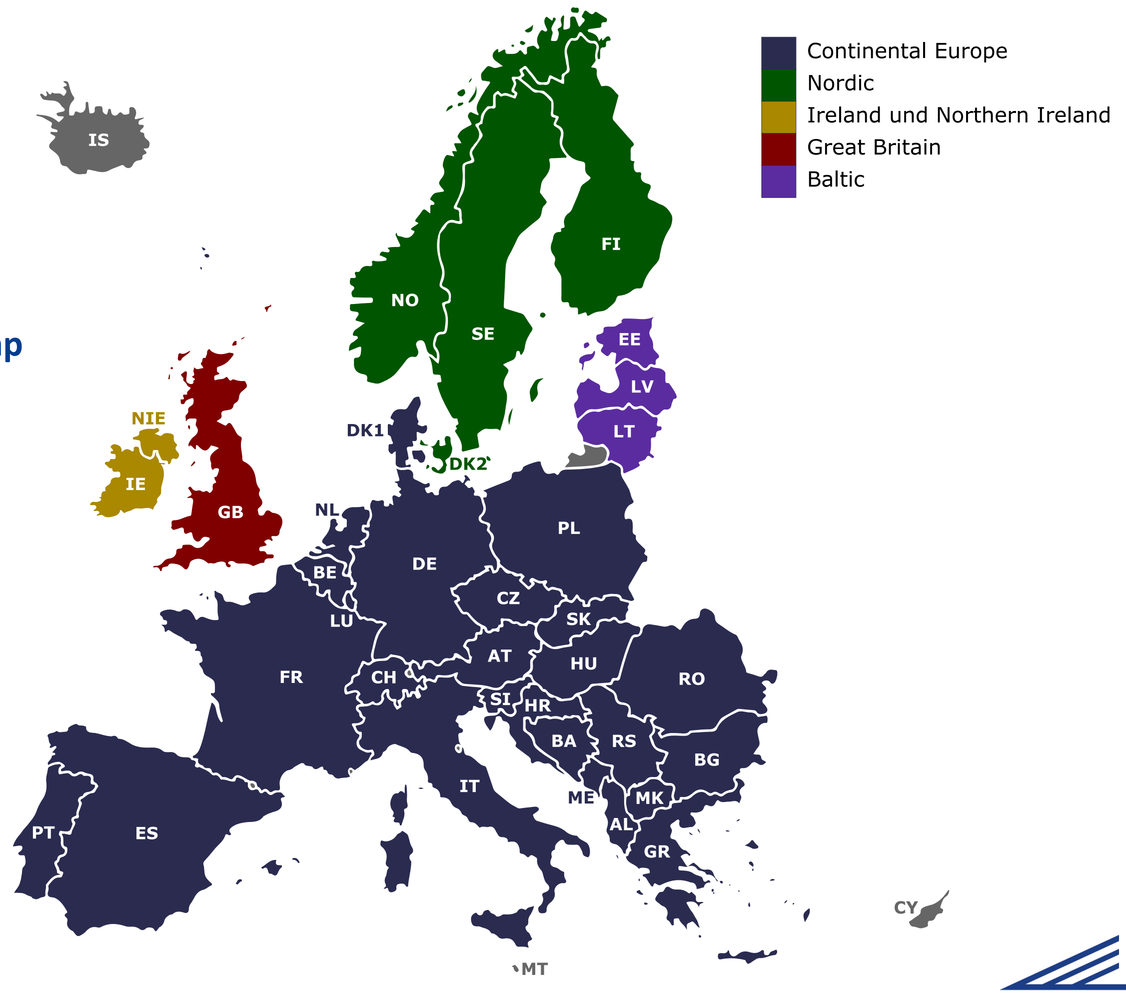
New Actors on Stage

Upcoming Grid Code Requirements for Storage Systems (in Europe)

Bernhard Schowe-von der Brelie | Mansoor Ali | Frederik Kalverkamp



Agenda

- [Short introduction to FGH]
- Scene Setting – Background and Introduction
- Definitions on Electric Storage Systems
- General Framework for Ancillary Sercices of Electric Storage Systems
- Status Quo on Implementation
- Compliance Schemes
- Summary & Outlook

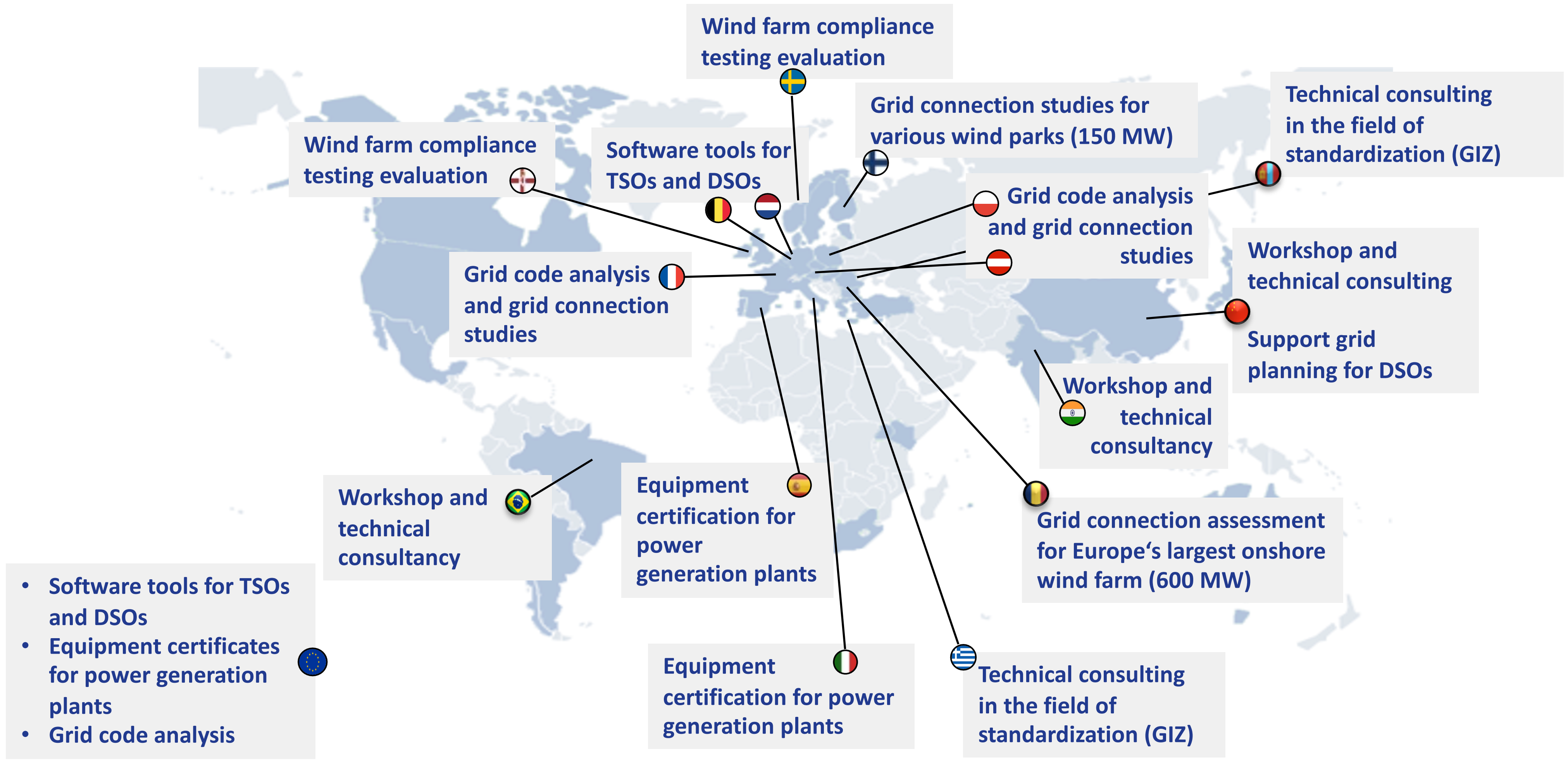
Our basis – exploring & networking knowledge

- **Research and Development**
  - Applied research for an efficient and secure supply of electrical energy in a non-profit research association **since 1921**
- **FGH Academy**
  - Conferences, seminars, workshops, forums, and webinars on FGH's fields of competence
- **Committee work for technical standards**
  - Participating in international, European and national working groups and steering committees on standardization activities

Our exploitation – for the benefit of tomorrow's power systems

- **Electrical grids**
  - **Network optimisation** with modular software and algorithms (INTEGRAL)
  - **Grid and system analyses**
- **Power system & power generation equipment**
  - **Grid code analyses & monitoring** and respective services
  - **Grid integration studies & services**, PGU/PGM modelling, electrical planning of PGMs; software tools
  - **(Classical) Power System Equipment** – asset management, fault analyses, ICT, …
- **Accredited certification, testing and inspection**
  - Laboratory and field measurement, type testing, PGU & PGM certification

Energising expertise – extensive grid code consulting and services, worldwide



Grid Codes on Storage Systems – a gap to be closed

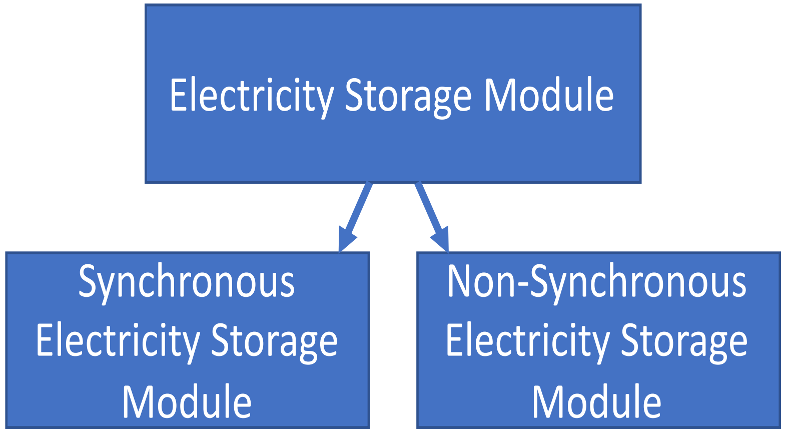
- The European Network Code *Requirements for Generators* (ENC RfG) did not address storage systems with regard to grid code provisions at all – except for pump hydro storage (export mode only)
- However, the view on storages, especially electric storage systems (ESS), has significantly changed
  - Growing importance toward a full-renewable energy scenario for balancing intermittent generation and load
  - The European Green Deal and respective climate policies will accelerate the pathways for broad ESS appliances
  - Especially for inverter-connected, low- to mid-scale but mass-implemented dispersed ESS this opens a wide range of ancillary services for the benefit of the power system
- The European Stakeholder Committee Grid Connection (GC ESC) has launched the Expert Group Storages in 2018
  - to provide precise definitions and applications of storage systems to be connected to the power grid
  - to develop proposals for the further revision of the European Network Codes with enhanced provisions on ESS
  - to give recommendations to ACER
- As well, initial national grid code implementation are available

Definitions by the GC ESC Expert Group (I/II)

„Electricity storage" means the conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy.

- To be distinguished from a general energy storage, e.g. as defined within the EU Clean Energy for all European Package, which allows the "reconversion of such" (stored) "energy into electrical energy or use as another energy carrier".

- Furthermore, the Expert group has introduced two categories of ESS technologies alongside the Power Generation Module (PGM) definitions of the ENC RfG
  - **Synchronous Electricity Storage Modules:** where, the energy conversion (i.e. charging or discharging) of the electrical energy is done through one or more synchronous machines connected to the electrical network with a single connection point to the system.
  - **Non-Synchronous Electricity Storage Modules:** here, the energy conversion (i.e. charging or discharging) of the electrical energy is done through an asynchronous machine or through a power electronic converter connected to the electrical network with a single connection point to the system.

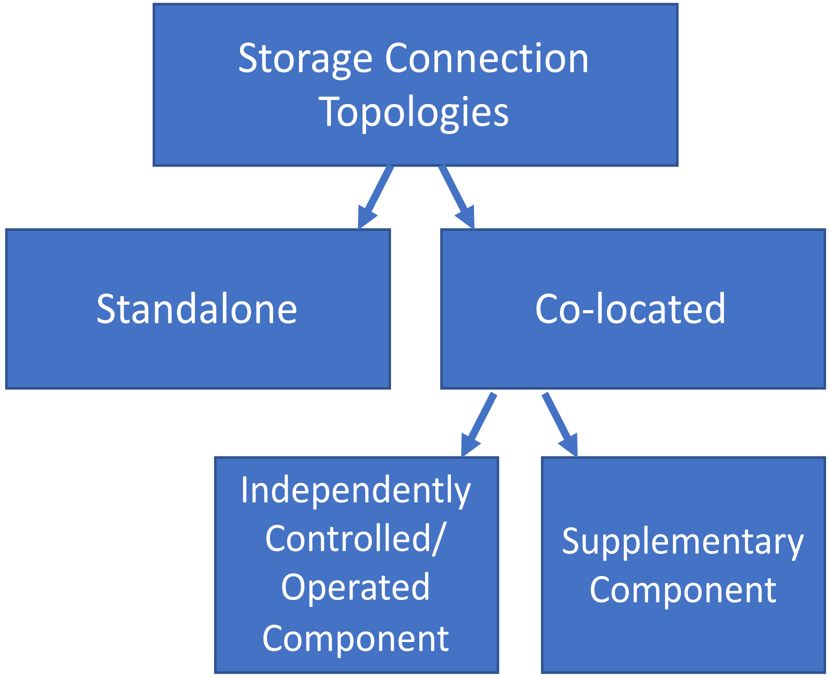


Source: GC ESC Expert Group Storage; Illustration by FGH

Definitions by the GC ESC Expert Group (II/II)

- Furthermore, the Expert group gave a distinction on the **connection topology** of storage systems:
  - **Standalone storage system:** A facility comprising solely of storage units which are controlled as one or more Electricity Storage Modules for their own
  - **A co-located storage system:** Here, the storage system and additional generation and/or demand/load is installed at a joint facility with a single point of connection to the power system.

    Their operation is further differentiated:
    - **Independently Controlled/Operated Components:** Here, the operation of the storage device is independent from the operation of other parts of the facility (generation/demand). In that case, it is possible to have the storage device running when the other component(s) of the facility is (are) switched off.
    - **Supplementary Components:** Here, the operation of the storage device is linked to the operation of the generating unit/demand unit. Hence, the storage system cannot be independently controlled (includes DC-connected ESS).



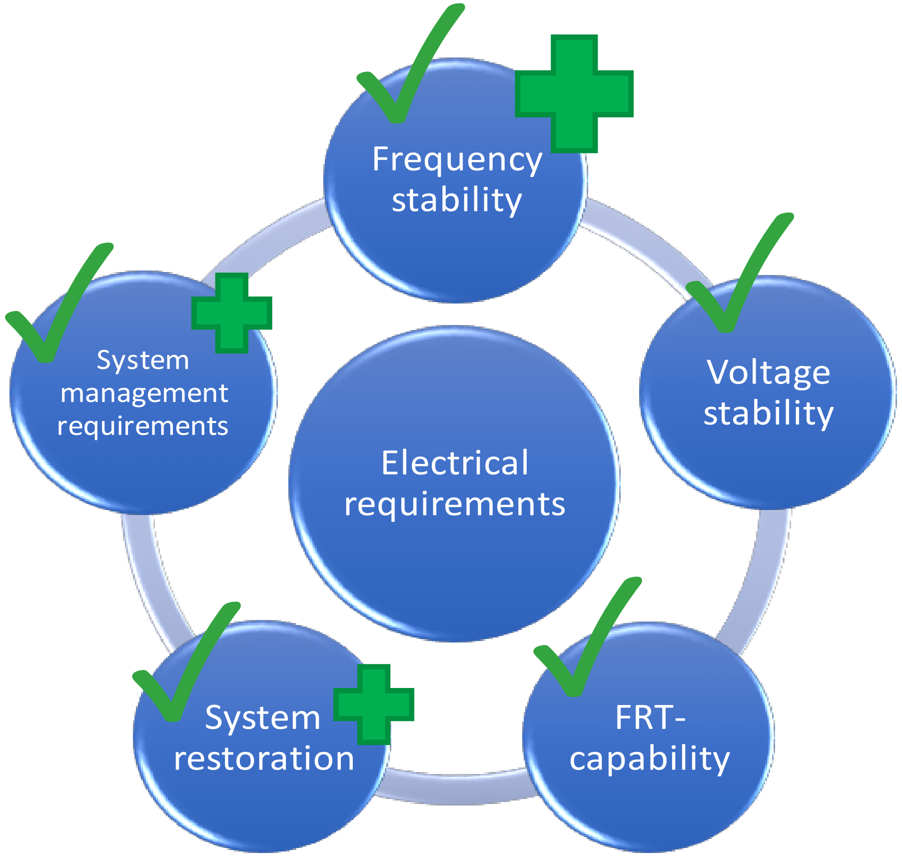
Source: GC ESC Expert Group Storage; Illustration by FGH

Agenda

- Scene Setting – Background and Introduction
- Definitions on Electric Storage Systems
- **General Framework for Ancillary Sercices of Electric Storage Systems**
- Status Quo on Implementation
- Compliance Schemes
- Summary & Outlook

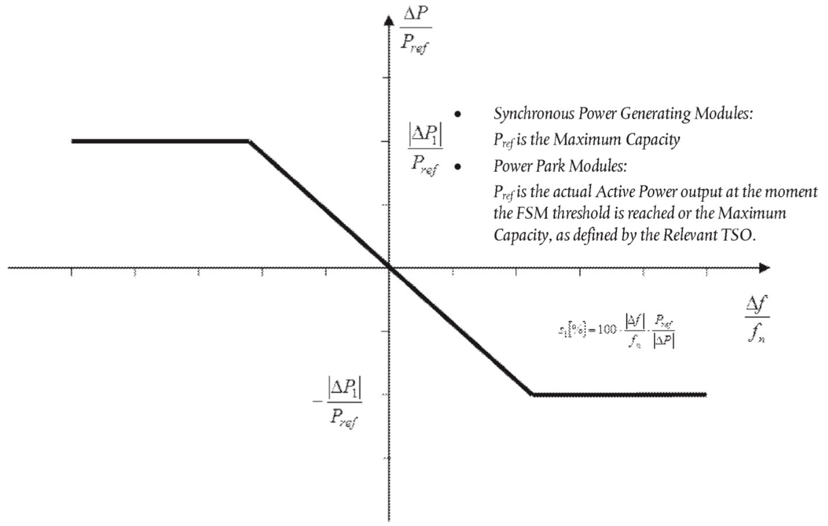
Particular contributions of Electric Storage Systems to Grid Code provisions

- ESS provide the full range of ancillary services like PGM in generation mode and add additional surplus:
  - As by definition, ESS provide a **bi-directional power flow**. Hence, active power control is not only restricted to the generation mode but can also be expanded to the **consumption mode**.
  - Unlike renewable PGM, ESS are **not depending on volatile primary energy sources**, which enables the utilization of ancillary services by these technologies independently of the availability of such primary technologies – in terms of local and temporal availability, hence, increasing their robustness.
  - Moreover, there is no underlying mechanical primary energy conversion like in wind energy converters or synchronous generators and, in general, also most battery systems are more immediate than the MPP tracking in PV systems. Hence, the dynamics of an ESS can be quicker for the benefit of **fast response services on power supply.**



I. Frequency stability

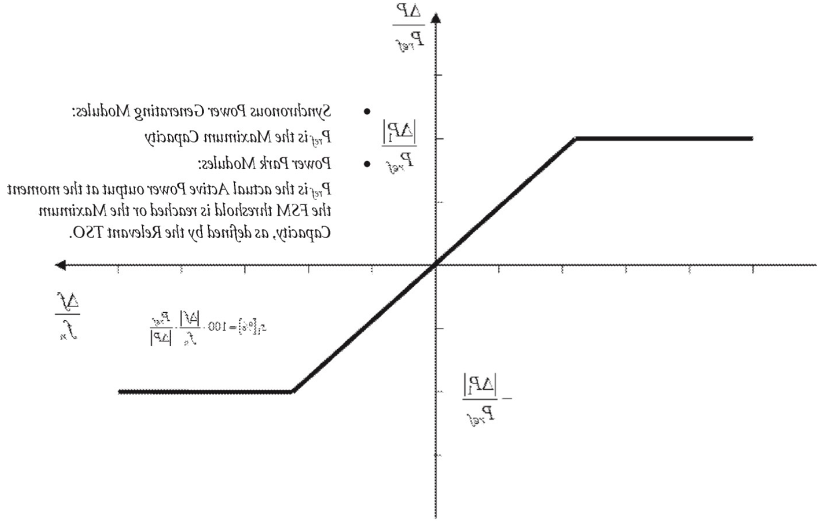
- Full advantage can be taken from the bi-directional and, in general, immediate power flow control:
  - **Active power control:** ESS shall be fully controllable by the system operator in terms of their **active power injection and consumption between zero and maximum power** at least in terms of discrete steps both **for charging and generation mode**. Priority rules in case of a participation of the storage system at the electricity balancing market have to be established.
  - **Frequency control:** the general scheme of the limited frequency sensitive modes for over- and underfrequencies (LFSM-O and LFSM-U) as for PGMs can be **extended for the charging mode** of ESS.



Active power frequency response capability of power-generating modules **(generation mode!)**
Source: ENC RfGII, COM

I. Frequency stability

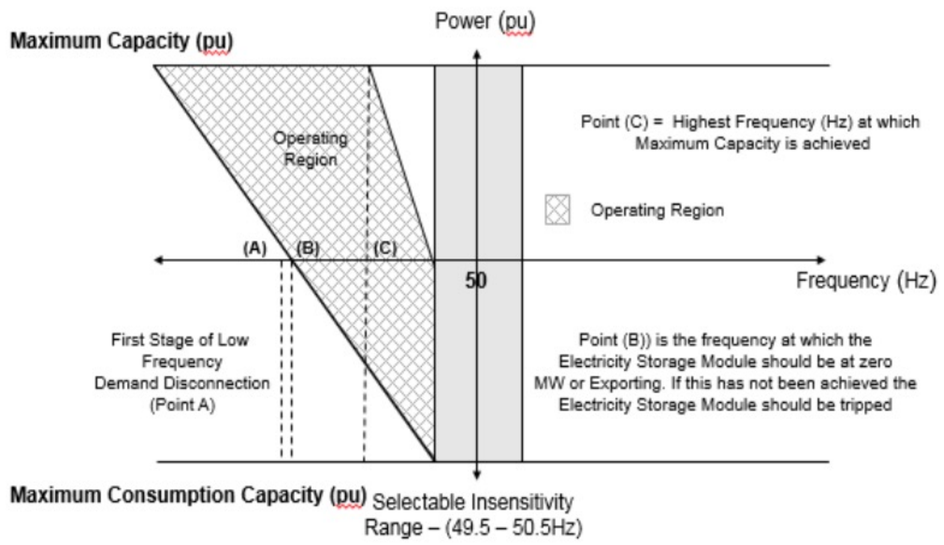
- Full advantage can be taken from the bi-directional and, in general, immediate power flow control:
  - **Active power control:** ESS shall be fully controllable by the system operator in terms of their **active power injection and consumption between zero and maximum power** at least in terms of discrete steps both **for charging and generation mode**. Priority rules in case of a participation of the storage system at the electricity balancing market have to be established.
  - **Frequency control:** the general scheme of the limited frequency sensitive modes for over- and underfrequencies (LFSM-O and LFSM-U) as for PGMs can be **extended for the charging mode** of ESS. Here, power consumption needs to be reduced (and shifted to generation) in case of under-frequencies and increased in case of overfrequencies. Also, a power generation may be shifted to consumption for high overfrequencies. Moreover, the requirements on **rise- and settling times** for the power transition may be more stringent due to the fast response capabilities of ESS.



„Illustration“ of Active power frequency response capability of power-generating modules
(„charging mode“!)
Source: ENC RfGII, COM; modified by FGH

I. Frequency stability

- Full advantage can be taken from the bi-directional and, in general, immediate power flow control:
  - **Active power control:** ESS shall be fully controllable by the system operator in terms of their **active power injection and consumption between zero and maximum power** at least in terms of discrete steps both **for charging and generation mode**. Priority rules in case of a participation of the storage system at the electricity balancing market have to be established.
  - **Frequency control:** the general scheme of the limited frequency sensitive modes for over- and underfrequencies (LFSM-O and LFSM-U) as for PGMs can be **extended for the charging mode** of ESS. Here, power consumption needs to be reduced (and shifted to generation) in case of under-frequencies and increased in case of overfrequencies. Also, a power generation may be shifted to consumption for high overfrequencies. Moreover, the requirements on **rise- and settling times** for the power transition may be more stringent due to the fast response capabilities of ESS.



Source: GC ESC Expert Group Storage; Final Report, Phase II

The GC ESC Expert Group has revealed a recommendation for a droop-characteristic in case of falling frequencies.

II. Voltage Stability

- **Reactive power control:** Additional requirements on reactive power ranges, set-point control and Q- or cos φ-characteristics shall be **expanded to the charging mode**.

III. FRT capabilty

- **UVRT & OVRT:** Fault-Ride-Through- (FRT-) capabilities to maintain in operation during power systems faults with gridside under- and overvoltages, shall be **expanded to the charging mode**. Moreover, non-synchronous storages shall actively contribute with a **well-defined fast-fault-current and active power gradient** to support the network voltage recovery.

IV. System restoration

- **Reconnection after faults:** Like PGMs, ESS shall take on the same provisions on reconnection in terms of voltage and frequency thresholds and active power gradients. In addition, the **resumption of the charging mode may be suppressed** by the system operator.

V. System Management and Protection Requirements

- **System (voltage) perturbation / power quality:** The requirements for the limitation of system disturbances including at least **harmonic emissions, flicker and voltage fluctuation, switching frequency emissions and unbalanced currents** shall be implemented for both, the charging as well as the discharging mode.
  Note: power quality issues are not subject to the ENC RfG as they do not provide a cross border impact. However, the GC ESC expert group agreed that voltage quality is becoming more important especially when connecting a growing number of high power-low energy ESS like electric vehicles to the low voltage network.

- **Electrical protection schemes and setting:** The provisions on the protection devices and their setting shall be adopted from those for PGMs. This includes system as well as machine protection.

- **Asymmetrical power flow:** Asymmetrical variants (1- or 2-phase) of (LV) storage systems shall only be permitted to connect to the grid until a certain power limit.

- **Maximum active power:** When operating an ESS in parallel to a PGM in co-located sites the sum of total power injection must not exceed the maximum active power as agreed with respect to the grid connection. For this purpose, an energy flow management system (e.g. current direction relay) is to be installed.

General remarks

- The GC ESC Expert Group gave detailed recommendation for the enhancement of future ENC to consider the contributions of ESS
  - within the ENC RfG with respect to the generation mode
  - within the ENC Demand Connection Code (DCC) with respect to the charging mode
  - within the ENC HVDC with respect to DC only applications
- Some of the requirements for the charging mode may be applicable for non ESS appliances as well (e.g. LFSM-U requirements for one-directional charge-only electric vehicles)
- Requirements may be stratified with respect to the voltage level of grid connection and total installed capacity.
  - Hence, a clustering similar to the type A-D definition within the ENC RfG seems appropriate.
  - The GC ESC Expert Group proposed to set up a common revised framework for the type definition in the future ENC.

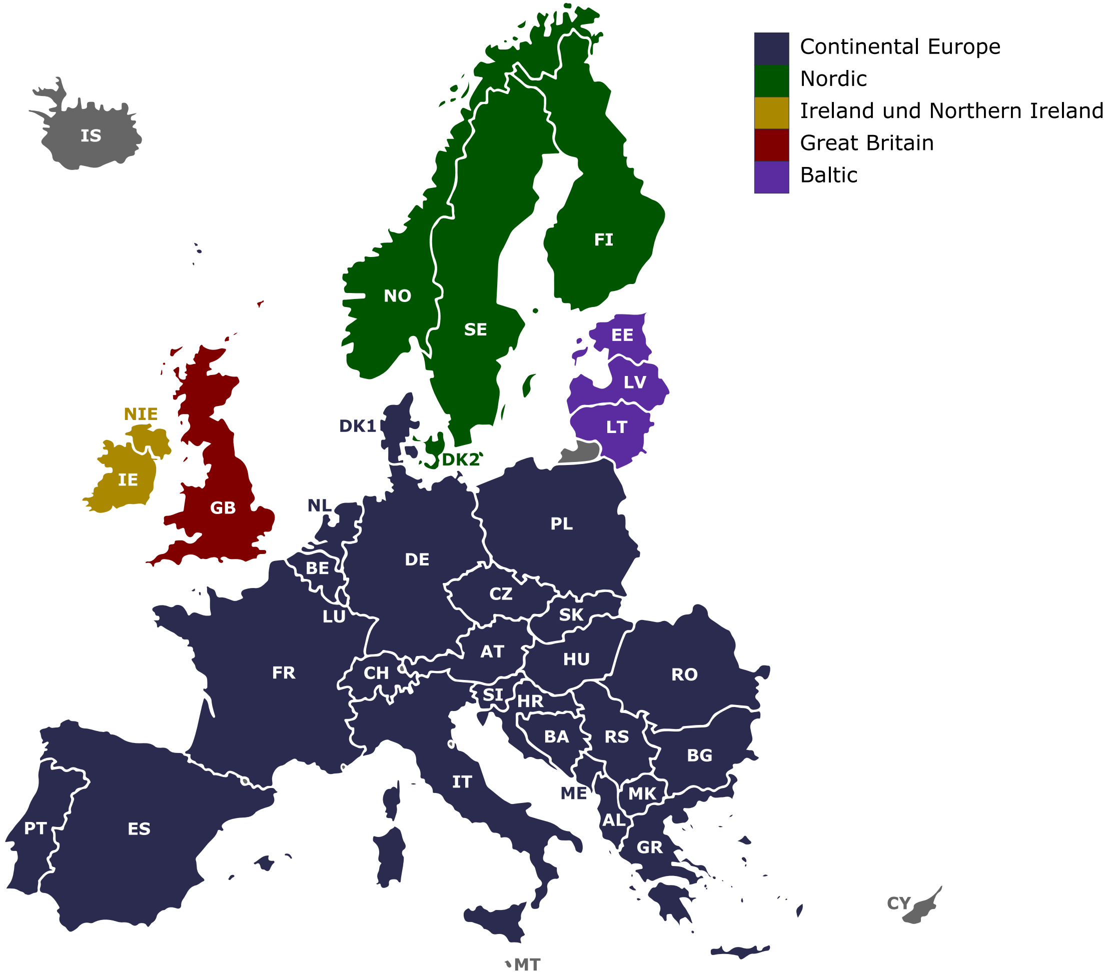
Agenda

- Scene Setting – Background and Introduction
- Definitions on Electric Storage Systems
- General Framework for Ancillary Sercices of Electric Storage Systems
- **Status Quo on Implementation**
- Compliance Schemes
- Summary & Outlook

FGH

FGH study survey on the national ENC RfG implementation on behalf of the COM - Study design

- National implementations of technical requirements observed from **26 MS** (excluding MT)
- **Additional 9 countries have been considered:**
  BA, CH, ME, RS, MK, GB, NIE, IS, NO
- **Six** countries with **no open** available implementation document in 2020:
  BG, BA, ME, MK, RS, CY
- Hence, a total of 29 ***MS+*** under analysis
- Study input cut-off date: **30.05.2020**
- The COM's main objective on an analysis of convergence-levels was enhanced by FGH by a **survey on storage requirements**



Source: FGH

FGH study survey on the national ENC RfG implementation on behalf of the COM - Study results on storage systems

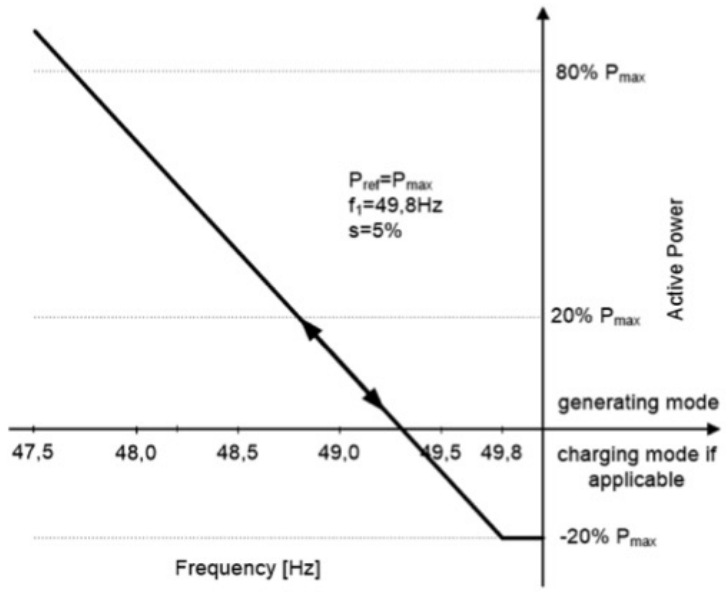
- not particularly productive … - as of mid 2020!

Belgium	A formal, legislative framework for the definition of technical requirements for storage systems has been implemented in the federal technical grid code and published in 2019. In a second step the DSOs' network codes C10 and C11 will be revised.
Germany	Grid code requirements for storage systems (ESS as well as electric vehicles in charge-only mode) have been incorporated in the latest VDE Technical Connection Rules in 2018: ▪ VDE-AR-N 4100 and VDE-AR-N 4105 for LV connection, ▪ VDE-AR-N 4110 for MV connection, ▪ VDE-AR-N 4120/4130 for HV/EHV connection
Great Britain	Integration of grid code requirements on storage systems into the G99 grid code has been adopted by the NRA OFGEM and published in 2020
Italy	Storage systems are subject to the existing grid codes CEI 0-21 for LV connection, CEI 0-16 for MV connection and the TERNA grid code for transmission system connection, but only with respect to a unit-type-definition for inverter-coupled electrochemical devices on their DC-side. A further extension to a more general class of ESS according is planned

Countries with started development: **Denmark, France, the Netherlands** and **Switzerland**

However: the European Standards (CLC) EN 50549-1/-2 lead the way

- Grid code provisions for power generating plants (equal to ENC RfG facilities, consisting of PGMs) connected to the LV distributions network (EN 50549-1) and to the MV distribution network (EN 50549-2), published in 2019
- In general, all requirements for PGMs are expanded to EESS (Electrical Energy Storage Systems, equal by definition to ESS) in both, generating and charging mode
- For LFSM-U/LFSM-O additional requirements for ESS are defined:
  - For LFSM-O: ESS in charging mode shall not decrease and should (if possible) increase their charging power according to a defined droop characteristic (with given frequency thresholds)
  - For LFSM-U: similar to the GC ESC expert group's recommendation, the ESS should shift from charging to an export mode
  - Note: no more stringent, i.e. faster transition requirements on LFSM-U/-O active power control are defined, as for example in Germany



Source: EN 50549-1/-2

FGH

Summary

- Taken together, the European standards, the first implementations in European national grid codes and the recommendation of the GC ESC expert group tackle all the capabilities as listed in the last chapter
- As grid code development will further evolve, new features are already in sight, e.g. the utilization of grid forming converters, that will have also an impact on respective requirements on storage systems.

Agenda

- Scene Setting – Background and Introduction
- Definitions on Electric Storage Systems
- General Framework for Ancillary Sercices of Electric Storage Systems
- Status Quo on Implementation
- **Compliance Schemes**
- Summary & Outlook

Still a missing link to let grid codes become effective

- Compliance schemes on storage systems' grid code conformity are **mostly missing** in the national regulation alongside the hesitant implementation of the technical requirements themselves (just like for PGM grid code conformity as well…; cf. WIW19-262).
  In general, for the generation mode most countries request the same manners of conformity statements (e.g. measurements, simulations, certificates) as for PGMs (if defined)
- Even in countries with advanced formal certification schemes on PGMs and well-defined grid code requirements on the charging mode of storage systems (e.g. Germany), respective compliance provision on storage systems remain **quite vague or less stringent** (e.g. approval of manufacturer's declarations) or are equipped with **generous transition periods**
- CLC is developing a testing standard (**CLC TS 50549-10**) for confirming grid code conformity with respect to EN 50549-1/2 including storage systems; to be published in 2022
- The early and stringent definition of respective compliance measures is highly recommend before storage systems are rolled out massively. Especially for the mass-market products of inverter-coupled ESS a **unit type certification** provides significant cost-efficiency for the system's compliance. (cf. WIW18-087)

Agenda

- Scene Setting – Background and Introduction
- Definitions on Electric Storage Systems
- General Framework for Ancillary Sercices of Electric Storage Systems
- Status Quo on Implementation
- Compliance Schemes
- **Summary & Outlook**

The foundations have been laid - the detail work is yet to come

- ESS will play a significant role in future power systems. Especially, inverter-coupled systems will represent a lot of appliances.
- Naturally, ESS can contribute a full range of ancillary system services to support the power network operation, which may even extend the capabilities of solely power generating modules
- The ENC do not address these features so far. As well, national grid codes are missing precise grid code provisions on ESS in most countries.
- The GC ESC Expert Group has given reasonable definitions and recommendations for the further development of the ENC taking into account ESS as well
- The European standards EN 50549-1/-2 provide a good reference for grid code requirements on ESS. As well, a respective testing guideline (50549-10) is to be published in 2022.
- Respective compliance schemes muss complement grid code requirements in a reliable manner. Unit type certification provides a quite cost efficient way.
- Grid code provisions will for sure further develop … !

Thanks for your attention

References to further information

GC ESC Expert Group: https://www.entsoe.eu/network_codes/cnc/expert-groups/;

FGH study: https://op.europa.eu/en/publication-detail/-/publication/ee9ecda7-6788-11eb-aeb5-01aa75ed71a1/

Bernhard Schowe-von der Brelie

+49 241 997 857 232

Bernhard.Schowe@fgh-ma.de

Mansoor Ali

+49 241 997 857 255

SyedMansoor.Ali@fgh-ma.de

Frederik Kalverkamp

+49 241 997 857 259

Frederik.Kalverkamp@fgh-ma.de

FGH

www.fgh-ma.de/en

Electrical Grids | Power Generation Plants | Testing and Certification | Academy

FGH