Grid Forming Inverters
- A Way Forward

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ENTSO-E

- Who we are
- What we do

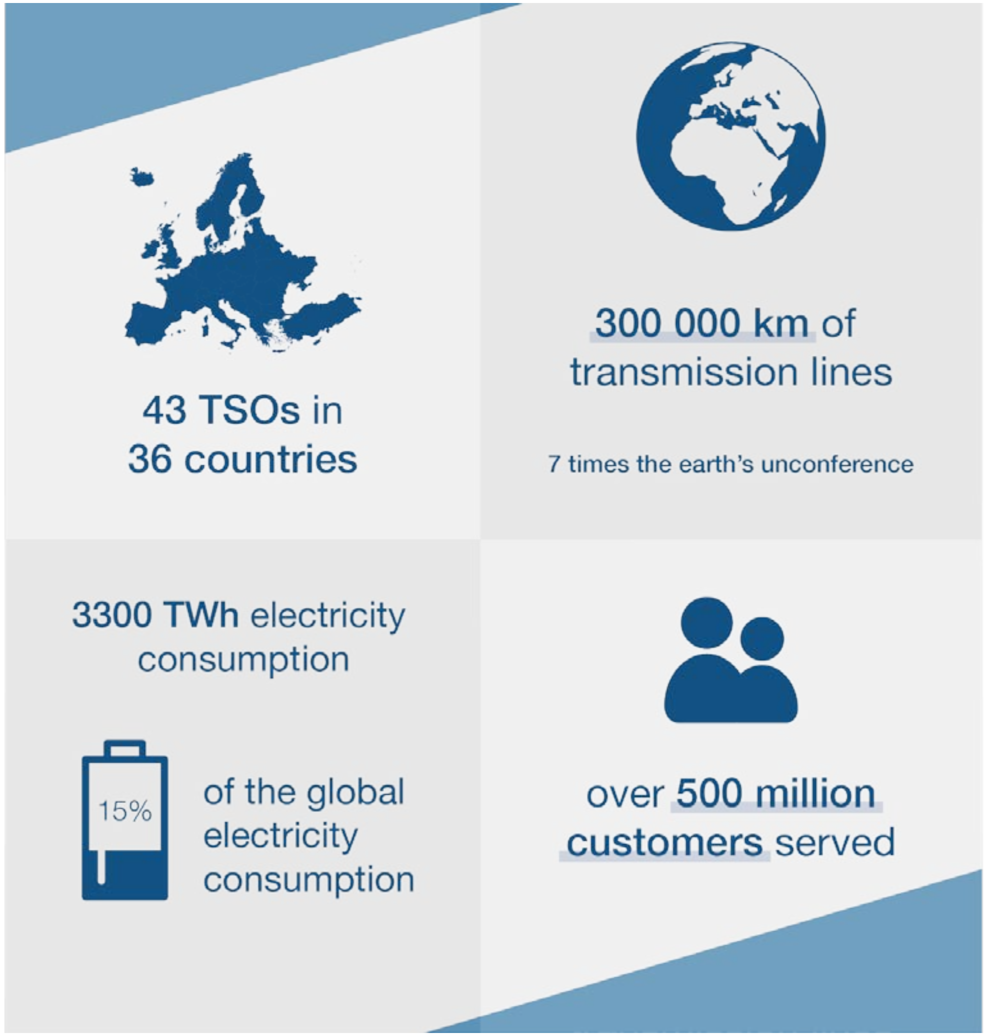
The European Green Deal

- EU energy policy framework

Grid Forming Capabilities

- Reasons for GFC
- Approach to GFC

Who we are


43 TSOs in
36 countries
300 000 km of
transmission lines
7 times the earth's unconference
3300 TWh electricity
consumption
15%
of the global
electricity
consumption
over 500 million
customers served

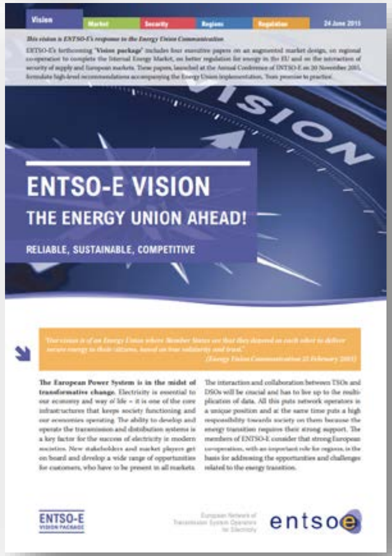
What we do …

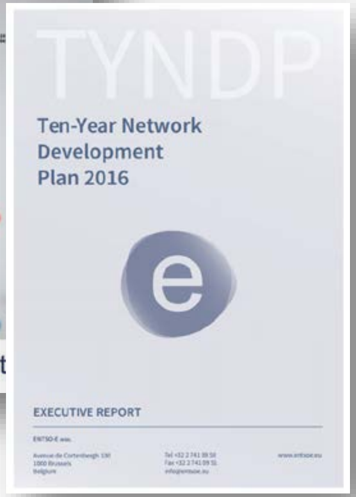
Contributing to the design and implementation of the Internal Energy Market

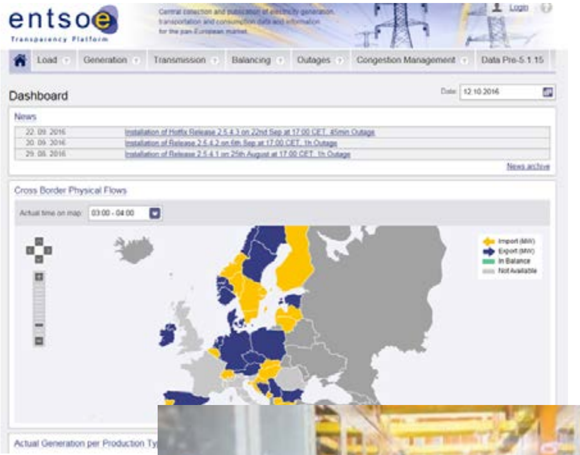
Providing regular reporting and recommendations for network development

Developing the necessary IT tools for enabling the implementation

network codes







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What is the European Green Deal?

The EU will be climate neutral in 2050.

An action plan with 10 main points and 50 actions.

Reaching this target will require action by all sectors of the economy.

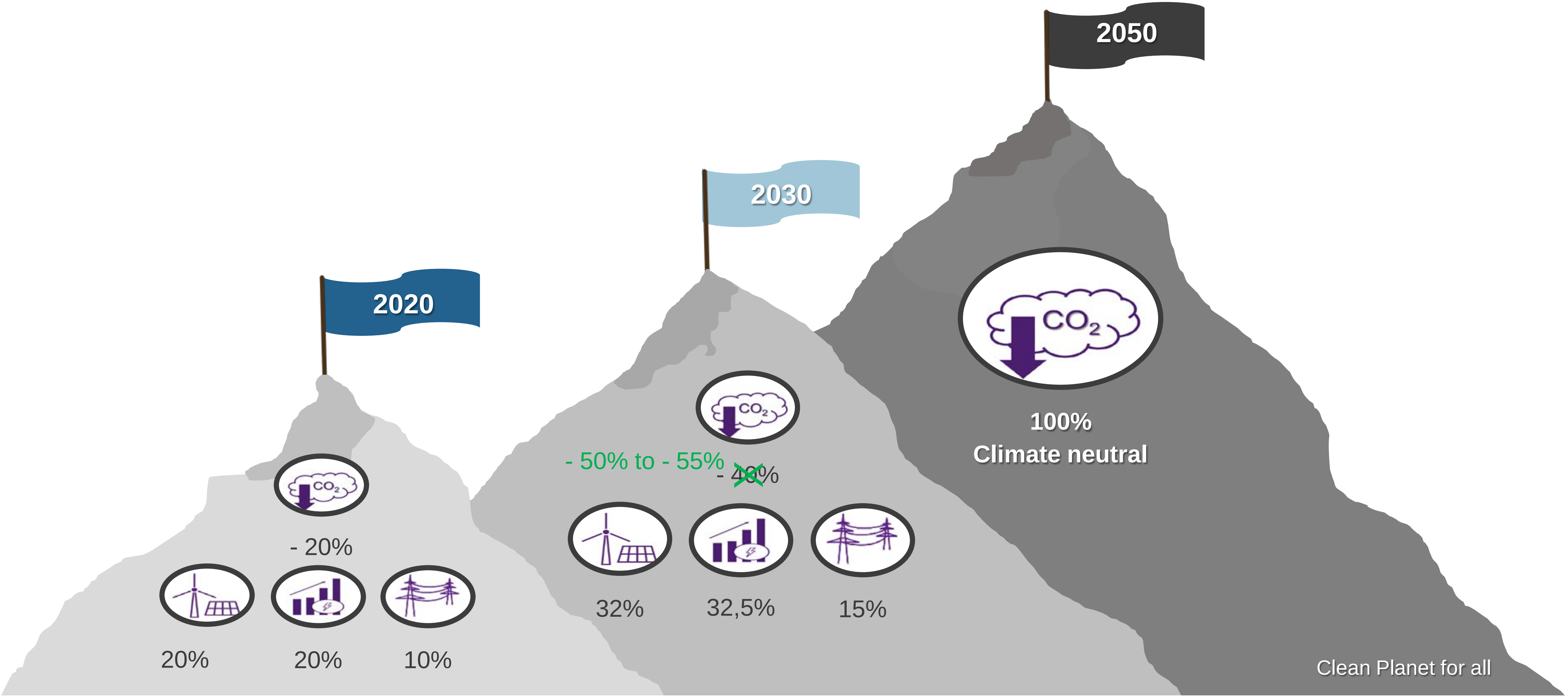
European Commission

Climate Law

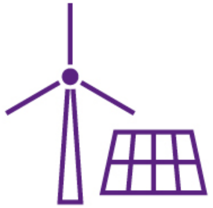
EU growth strategy

No one will be left behind.

Increasing the EU's climate ambitions



Clean, affordable and secure energy



Prioritise energy efficiency and develop a power sector based largely on renewable sources

Secure and affordable EU energy supply

Fully integrated, interconnected and digitalised EU energy market

The production and use of energy account for more than 75% of the EU's greenhouse gas emissions.

Source: European Commission

Challenges and opportunities for the energy sector

- Interconnection of energy systems
- Integration and development of renewable energy sources
- Increase energy efficiency
- Decarbonisation of the gas sector and smart integration across sectors
- Increase cross-border and regional cooperation

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I. High Penetration of Inverter Based Power Sources (HP IBPS) in European Power Systems – The Background

... from a centralised power system with large synchronous generation units towards a decentralised power system in a distribution level.

... 8 European countries are expected to cover 100% of their instantaneous demand by RES – 22 countries to reach a 50% level.

... load flow patterns become volatile with increased reverse flows and faster voltage deviations.

... need for larger and more variable transits across the transmission corridors.

... Generation: massive power converter installations

... Demand: similar trends with power converters in motors, electric vehicles, etc.

... change the power system dynamic profile

1. displacement of synchronous generators
2. faster time constants inverters

II. Overview of challenges*) associated with HP IBPS

1. Decline of Total System Inertia (TSI)

2. Increase of risk of system splits

3. Reduction of short-circuit power levels

4. Reduced rotor angle stability of remaining synchronous generators

5. Reduced voltage stability

6. Risk of harmonic instabilities due to fast dynamic behavior of IBPS

*) Source: Technical Report „High Penetration of Power Electronic Interfaced Power Sources and the Potential Contribution of Grid Forming Converters“, ENTSO-E, Solar Power Europe, T&D Europe, Wind Europe, 2020

II. Reduction of TSI – The Background

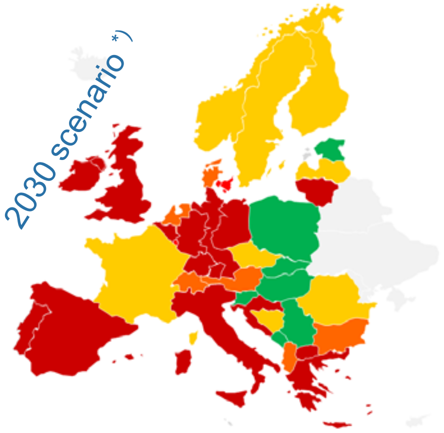
Total System Inertia (TSI)

Today: Normative loss of 3000 MW is controllable in the Continental Europe (CE) interconnected synchronous area

2030 scenario: TSI constant H declines from traditionally 5-6s down to below 2s

2040 scenario: Progressive decrease of TSI, even observable today in smaller SAs than CE with constant H<1s for about 20% of the year

2030 scenario *)

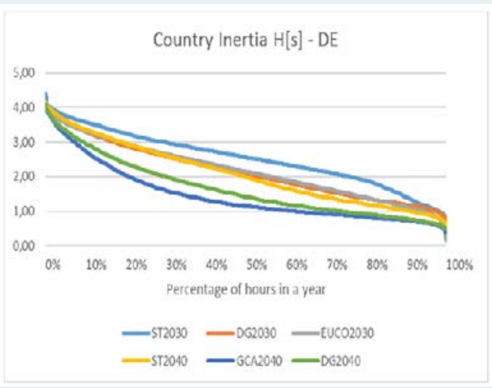


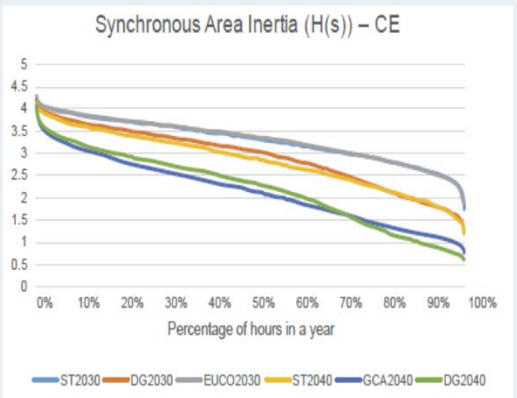
Inertia contribution colouring code:

- Green H ≥ 4 s Very good contribution
- Yellow 3 s ≤ H < 4 s Good contribution
- Orange 2 s ≤ H < 3 s Marginal contribution
- Red H < 2 s Limited contribution

! Action needed !

*) Source: Dr. Ralph Pfeiffer, A European View on Grid Forming Inverters and Network Codes, Presentation ESIG 2019, Albuquerque, 20th March 2019





II. Reduction of Short Circuit Power Level – The Background

Short Circuit Power Level
(SCPL)

Already today: Different levels of SCPL are reported in many CE countries

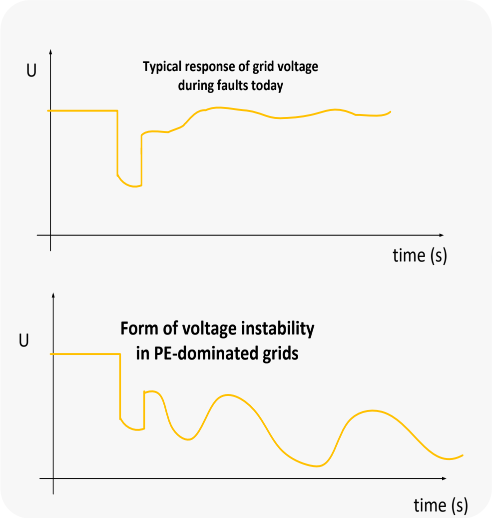
High SCPL: Reliable Fault-Ride-Through (FRT) capability of PGMs, strong rotor angle stability of SPGMs

Low SCPL: Deeper voltage dips, hence loss of FRT capability

Robust and **stable operation of IBPS** with today's Grid Following capability significantly **rely on correctly** working **Phase-Locked Loop** (PLL) controls

Potential **IBPS instability** is even **intensified** in areas **with low SCPL** and in **weak grid connections** environment

II. Reduced Voltage Stability – The Background



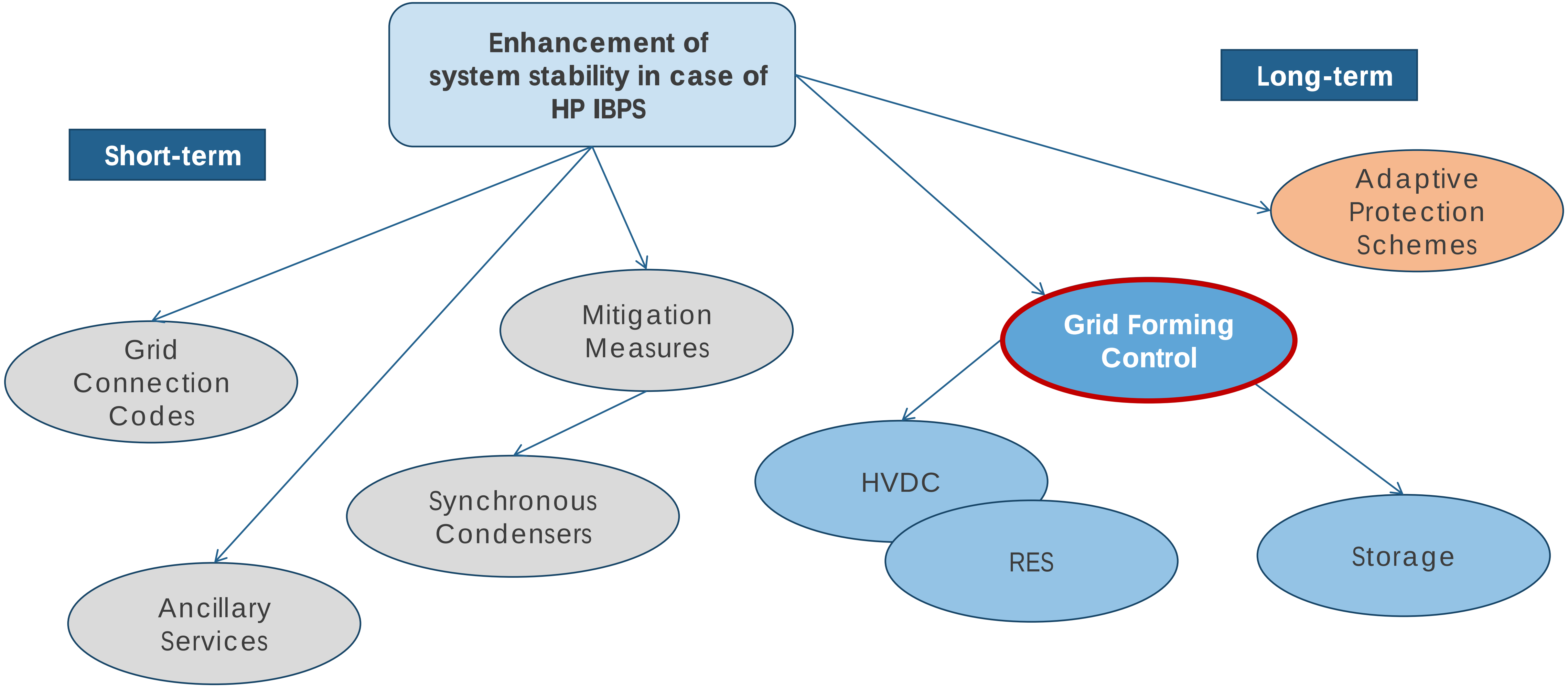
Voltage (In)Stability

- **Instability means:** Progressive voltage rise and fall up to voltage collapse
- Loss of generation regarding FRT capability
- Lack of reactive power sources / excess of reactive power sources
- Altered static and dynamic voltage dependence on load
- Inadequate support to post-fault system voltage restoration
- **100% IBPS means:** Response within the first quarter cycle (5ms) to avoid system collapse

II. At a glance: Consequences of HP IBPS in European Power Systems

Causes	Consequences
1. Reduction of the **TSI** (Total System Inertia)	➢ Decline of system constant H ➢ Increase of RoCoF values (Hz/s) in frequency containment period
2. Risk of **systems splits**	➢ Separation of system into asynchronous zones ➢ Power imbalances of the separated islands after the split ➢ Islands may consist close to 100% IBPS with severely reduced system strength ➢ Inefficient LFDD measures (Low Frequency Demand Disconnection)
3. Reduction of **short-circuit power** levels	➢ Deeper and geographically widespread voltage dips ➢ Increased risks of trips from under-voltage protection ➢ Risk of decreased transient stability of SPGMs
4. Reduced **rotor angle stability** of remaining synchronous generators	➢ Power oscillations and/or reduced damping of oscillations ➢ Reduction of transient margins
5. Reduced **voltage stability**	➢ Progressive voltage rise and fall up to voltage collapse ➢ Voltage dip-induced frequency dips ➢ Lack / excess of reactive power sources ➢ Altered static and dynamic voltage dependence
6. Risk of **harmonic instabilities** due to fast dynamic behaviour of IBPS	➢ Appearance of SSR (Sub Synchronous Resonances) and SSI (Super Synchronous Instability) ➢ Lack of sinks for low order harmonics and inter-harmonics

III. ENTSOE "One Vision 2030" Roadmap towards HP IBPS



IV. IBPS and their capabilities

- **3 classes** of **IBPS** with different **levels** of **capabilities**

  Class 1 – Focus on ***„Survival“*** of type A PPMs

  Class 2 – Focus on ***„Advanced Control“*** of type B, C, D PPMs and HVDC Converter Systems (HCS)

Class 1	Class 2
„Basics“	Class 1 + **„Advanced Control“**
• Full frequency operating range • Full voltage operating range • Basic reactive controls • LFSM-O • Compliance with power quality requirements	• Fault Ride-Through • Steady state voltage control • Dynamic voltage control • FSM • LFSM-U • Damping provision • Fast Fault Current Injection
• Type A PPMs	• Type B, C, D PPMs + HCS

IV. IBPS with real Grid Forming Capabilities *)

- **Definition** of **7 grid forming capabilities** of **IBPS**

Class 1 – Focus on ***„Survival“*** of type A PPMs

Class 2 – Focus on ***„Advanced control“*** of type B, C, D PPMs and HVDC Converter Systems (HCS)

Class 3 – Focus on ***„Operation under normal, disturbed and emergency states“*** without reliance on synchronous generators

Class 3
Class 1 + Class 2 +***„disturbed & emergency states“***
1. Creates **system voltage** 2. Contributes to **TSI** (limited by energy storage capacity) 3. Supports **system survival for efficient LFDD** in case of rare system splits 4. Contributes to **fault Level** 5. Acts as a **sink to counter harmonics** 6. Acts as s**ink to counter unbalance in system voltage** 7. Controls act to **prevent adverse control system interactions**
• Selected type B, C, D PPMs + HCS

*) Source: Technical Report „High Penetration of Power Electronic Interfaced Power Sources and the Potential Contribution of Grid Forming Converters“, ENTSO-E, Solar Power Europe, T&D Europe, Wind Europe, 2020

V. The Actual Status on Grid Forming Progress in Europe

- **The** present **situation …**
  - Technical Group High Penetration (**TG HP**) of ENTSO-E has performed **analysis on IBPS** in Europe.
  - TG HP has reported the results to the Grid Connection European Stakeholder Committee (GC ESC).
  - **Final report on IBPS** has been published on 30th January 2020.

- Some **vendors …**
  - … fear **increased manufacturing costs**.
  - … currently **don‘t anticipate a market** for grid forming capabilities.
  - … expect capabilities to be ancillary services.

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*) Source: Julia Matevosyan (Ercot), Grid Forming Inverters Be the Key for High Renewable Penetration, Presentation WIW2019, Dublin, 16.-18.10.2019

VI. How to introduce Grid Forming Capabilities to Future Power Systems

Question: Will there be a technical **need of grid forming capabilities** for secure operation of future power systems?

Answer: **Need** of grid forming capabilities is **irrefutable** …

Question: **How** can new PPMs/HCS with **grid forming capabilities** be **integrated** in future power systems? What are the **possibilities**?

Answer: A **differentiated view** is **irrefutable** …

- … Grid forming capabilities mandatorily implemented in the **Connection Network Codes**
- … Grid forming capabilities as **ancillary services** after **prequalification process**
- … a **combination** of both

VI. Grid Forming Capabilities: Integration in CNC vs. Ancillary Services

Grid Connection Requirements	Prequalification Criteria for Ancillary Services
➢ Capabilities to be requested mandatorily from all system users (e.g. all power generating modules)	➢ Capabilities to be requested from a part of all system users only
➢ Capabilities can be defined predominantly exhaustively in a network code and are of general application	➢ Features are project-specific and may vary significantly from site to site
➢ Non-mandatory requirements with objective decision criteria	➢ Non-mandatory requirements with flexibility with regard to possible service providers
➢ Capabilities with (costly) relevance to plant design	➢ Capabilities can be delivered within existing plant design or after modifications/extensions at reduced costs
➢ Long life-cycles of investments	➢ Retrospective application to existing users
➢ Urgency of implementation of the capability (at least 30% GFC at 100% PEIPS penetration)	➢ Liquidity of a market can be expected

VI. Using EC Amendment Process for CNC Integration of Grid Forming Capabilities

Quotation of Article 69(1) of REGULATION (EU) 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity:

*“**By 1 July 2025**, the Commission **shall review the existing network codes and guidelines** in order to assess which of their provisions could be appropriately incorporated into legislative acts of the Union … and **how** the empowerments for **network codes and guidelines** … **could be revised**.”*

Each Network Code can be revised only once in this period.

Entities with legitimate interests can submit amendment proposals to the Agency for the Cooperation of Energy Regulators (ACER); ACER evaluates, consults, consolidates amendment proposals and submits them to the European Commission.

The formal amendment process is not expected to start before 2021. ENTSO-E (like other stakeholders) will prepare its position on Connection Code amendments until the end of 2020.

Thank you for your attention!

Questions?

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