High Penetration of Inverter Based Generation in the Power System:

A Discussion on Stability Challenges and a Roadmap for R&D

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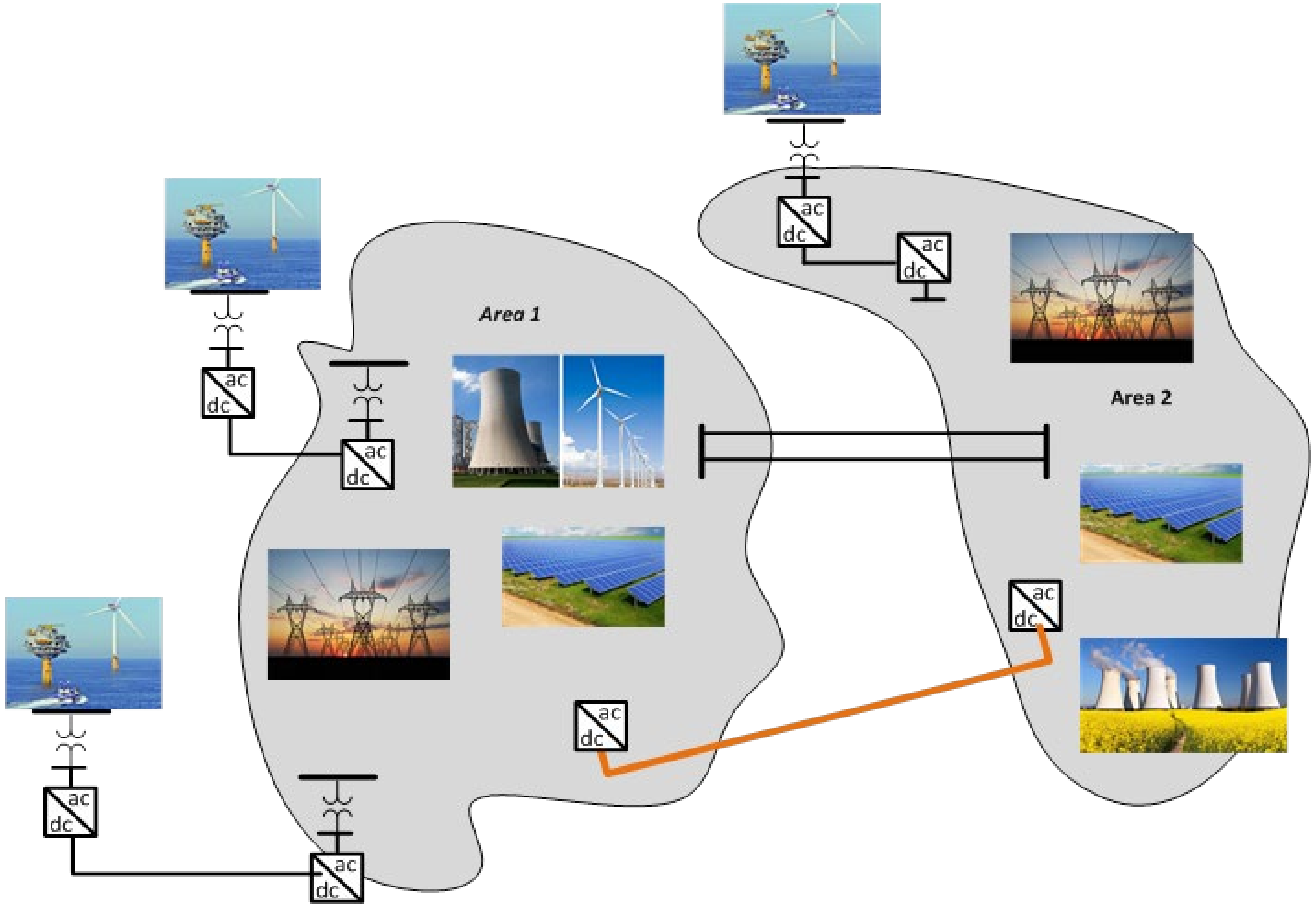
WG2: Security and System Stability

Power System Challenges

Roadmap towards PE Dominated Power Systems

Change in power generation structure

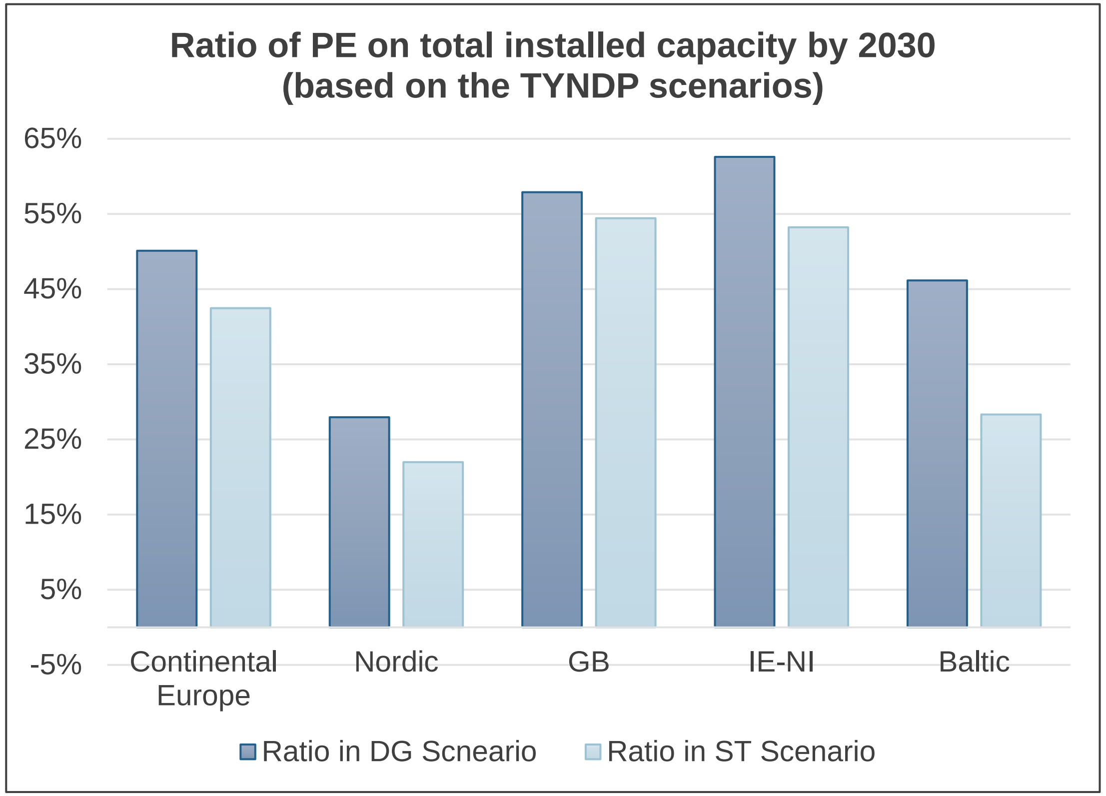


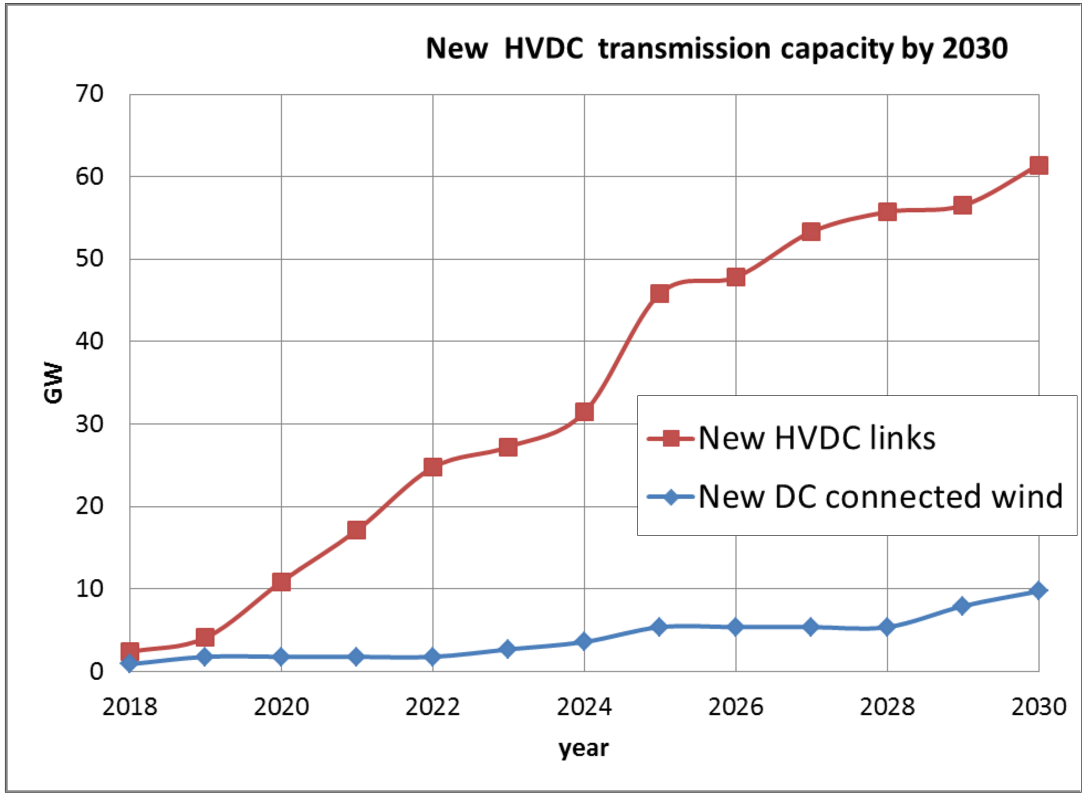
- Increasing share of power electronic interfaced generation (PEIG) in the grids
- Decreasing share of synchronous generation

Key questions:

- How to accommodate more PEIG in the power system?
- What do we do to maintain the same levels of security of supply?

Grids with high penetration of PE based generation and transmission





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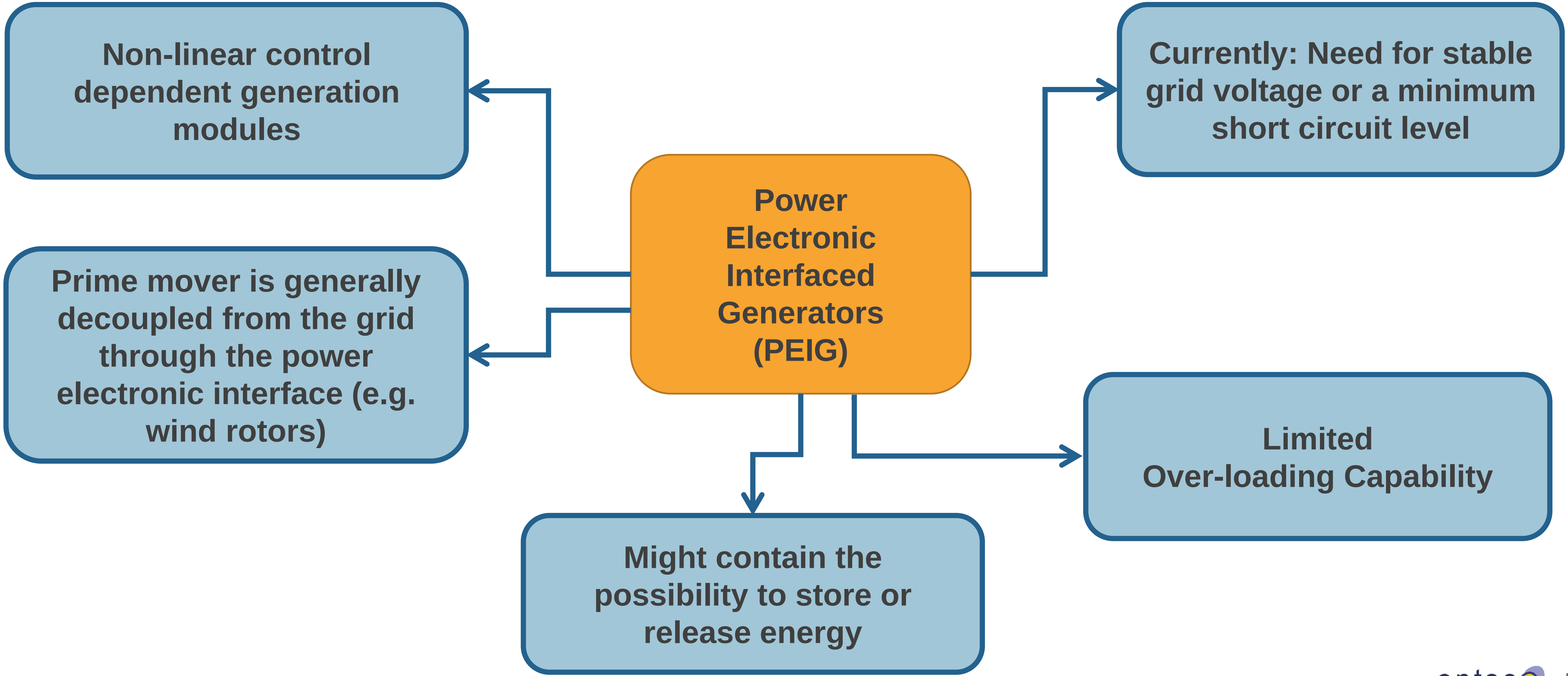
Why PEIG is different from conventional generation?



Association with Power system stability

PE-Based RES and HVDC systems currently provide

- No inherent synchronization effect
- No inherent system inertia
- Low short circuit currents

➡ **Possible Instabilities**

- Thorough analysis of interactions in order to avoid less damped oscillations
- Loss of synchronism from RES/HVDC if short circuit power is reduced below certain levels
- Loss of fault ride through capability and trip during grid faults (risk for voltage and frequency stability)
- Erroneous contribution to grid support functions (voltage, frequency control, synthetic inertia)

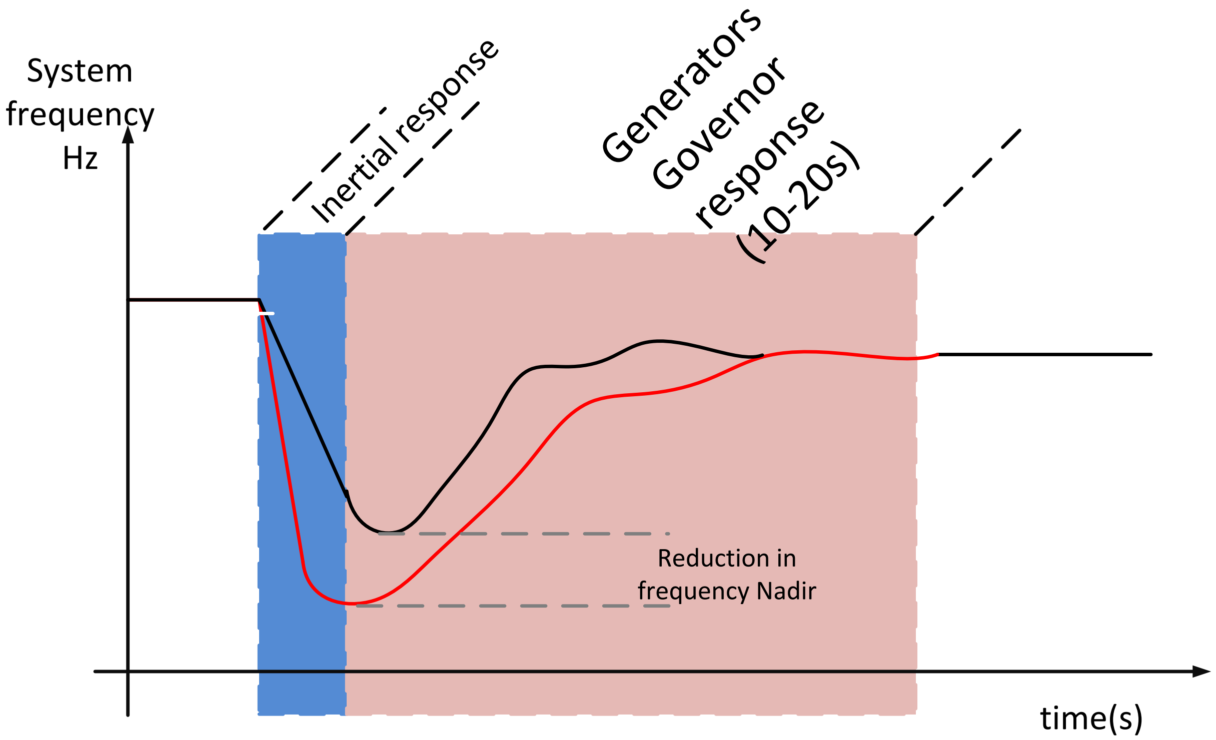
Main Operational challenges due to massive penetration of PEIG

Operational challenges (1/5)

Frequency stability challenges

Increased levels of PEIG and HVDC would reduce RoCoF and Nadir

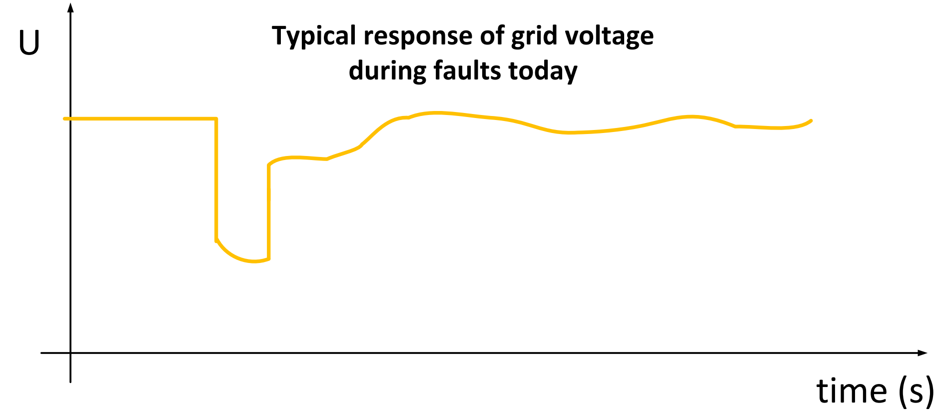
For the Continental European system, the case of system split becomes a critical case when high penetration of PEIG is considered as today

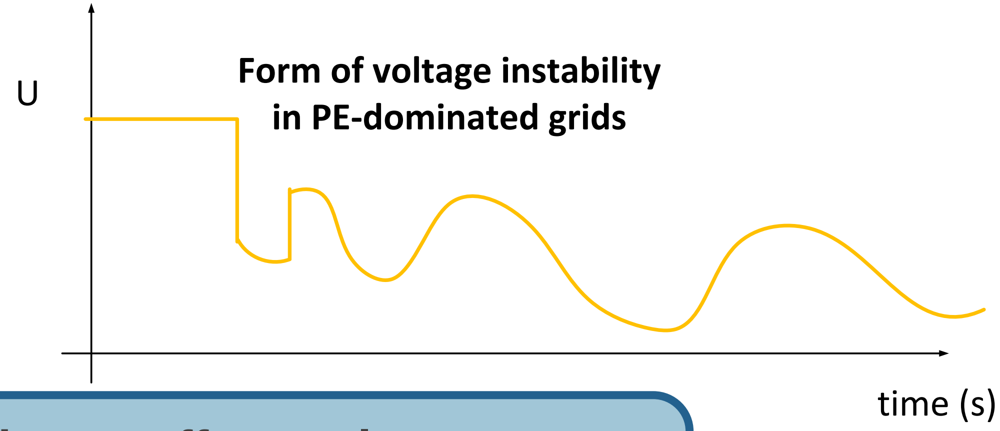


Operational challenges (2/5)

Voltage stability (short term)

- PEIG and HVDC can typically only inject between 1 and 1.2 times their rated current as fault-current.
- Wider propagation of voltage dips (the disturbance affects a larger geographic area), more noticeable effect in the medium and low voltage levels both leading to potential disconnection of distributed generation.

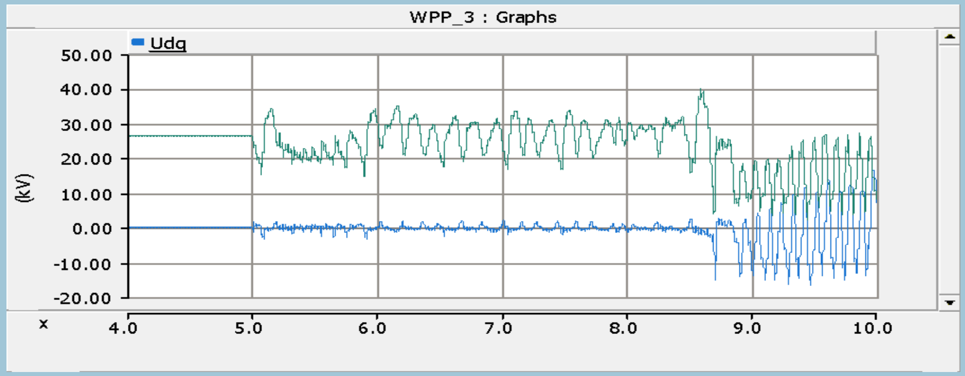




Operational challenges (3/5)

Control Interactions

Example of PEIG in a 75% PE grid



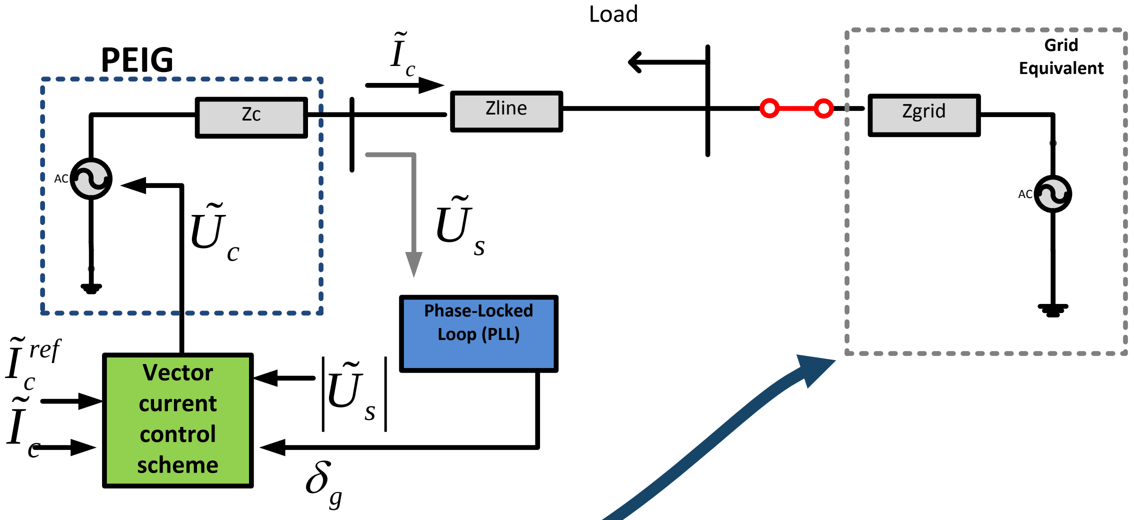
Control interactions of HVDC and PEIG with the grid resonance are mainly affected by the utilized control loops and electrical parameters of the external AC transmission grid impedance (including the level of grid stiffness)

The interoperability of PEOG/HVDC systems in a future PE-dominated grid is a challenge that TSOs have to address in order to ensure a certain level of power system security of supply

Operational challenges (4/5)

Voltage Formation

- PEIG robust and stable operation is based on the detection of sinusoidal voltage waveforms provided by the network
- This control principle is called "grid following" operation of PEIG, and leads to a potentially unstable situation in scenarios with high penetration of PEIG



Operational challenges (5/5)

Protection malfunction

Another risk associated to the reduced levels of short-circuit currents in the system is the malfunction of fault detection and protection schemes both for transmission and distribution systems

Malfunction of protection schemes and slow fault clearing can lead to rotor angle instability and cascaded effects

Future System Needs

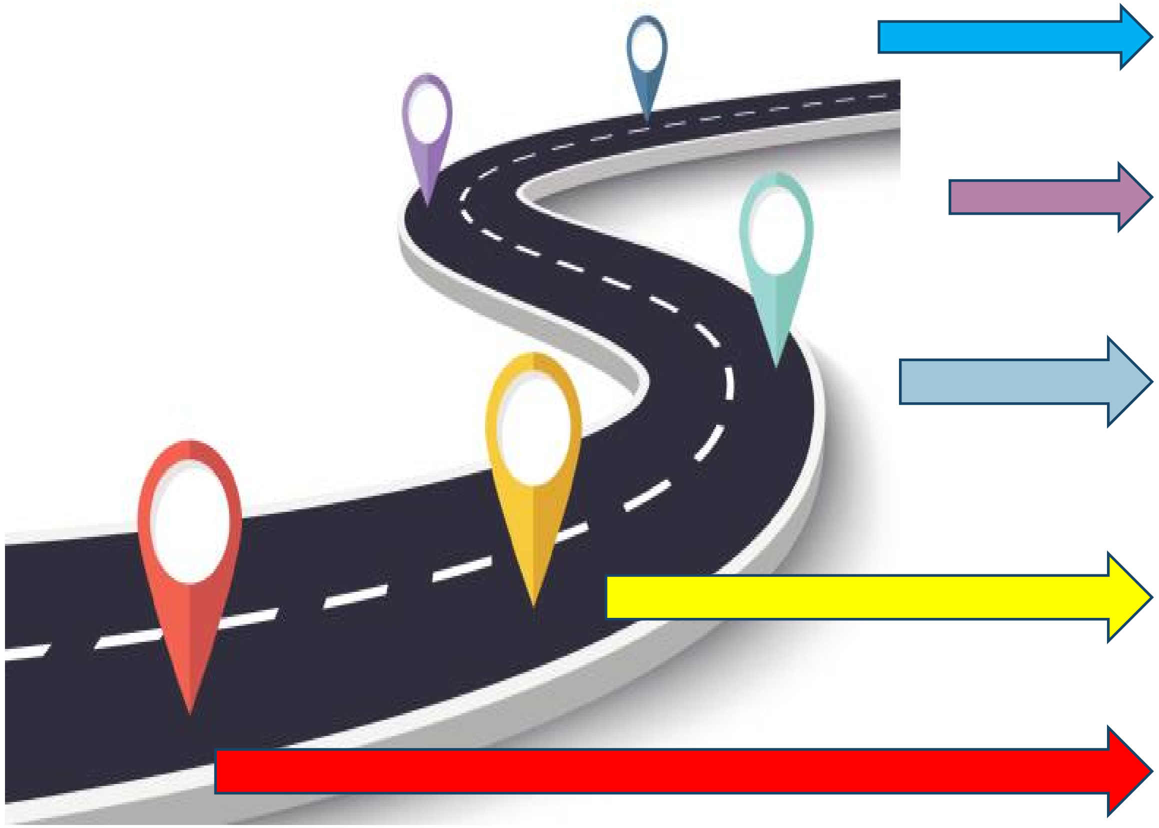
Compared to the past, power systems have an increasing demand of

- Flexibility
- Controllability
- Observability

Good News

- Potential of power electronic devices is not appropriately used yet
- PEIG and HVDC can deliver the required functionalities
- Appropriate planning required

Roadmap towards PE-Dominated Power Systems (incl. HVDC)



Enhancement of system stability

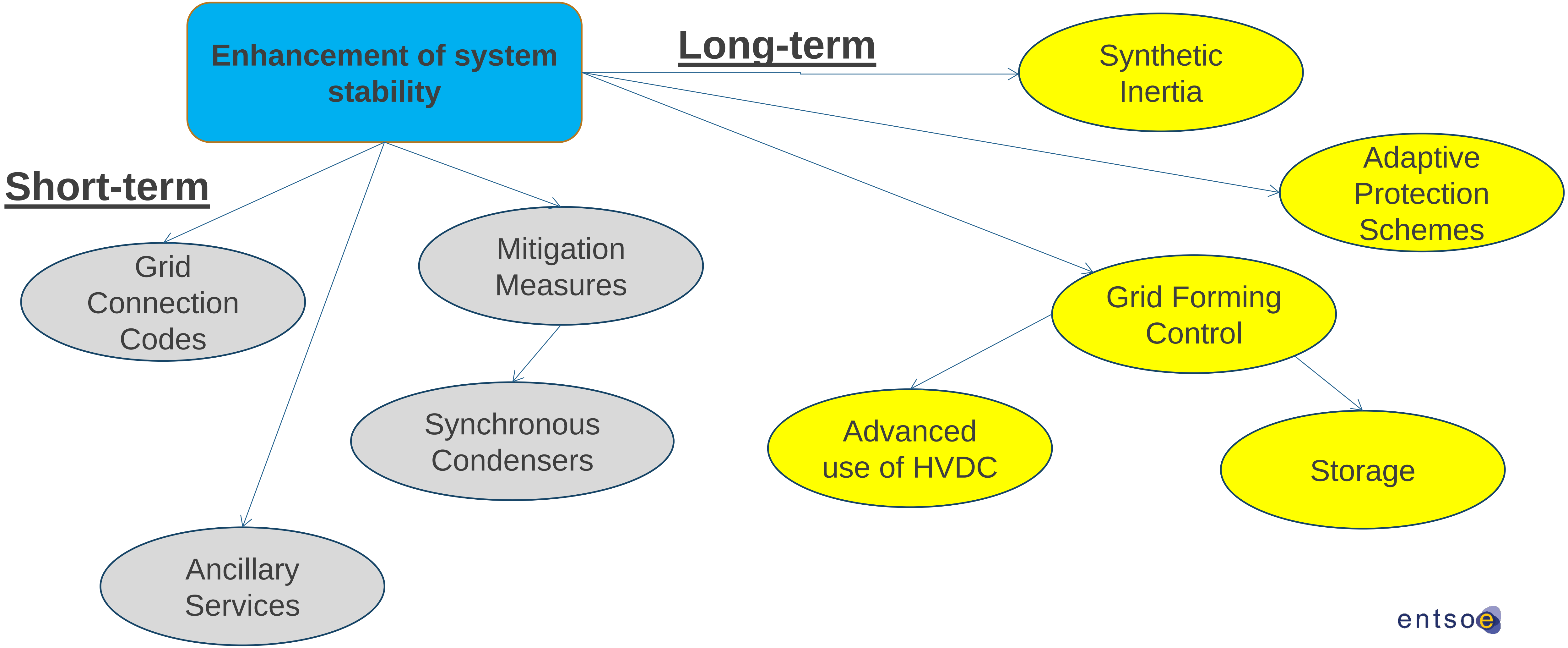
Enhancement of system observability

Enhancement of flexibility

Tools and advanced models

Enhancement of coordination

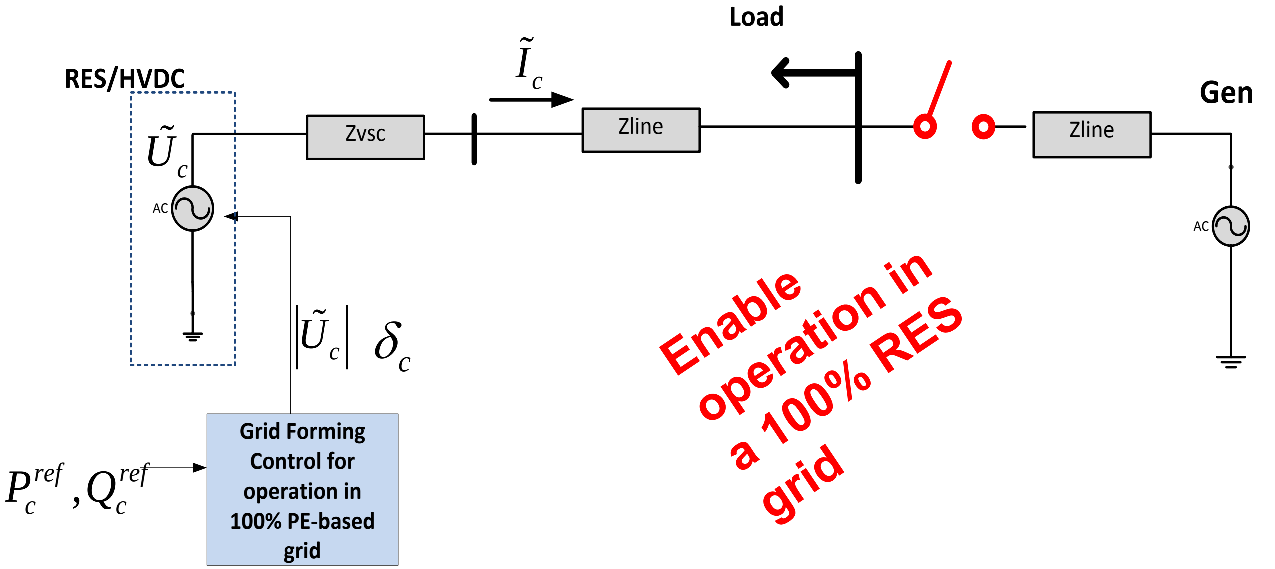
Roadmap towards PE-Dominated Power Systems (incl. HVDC)



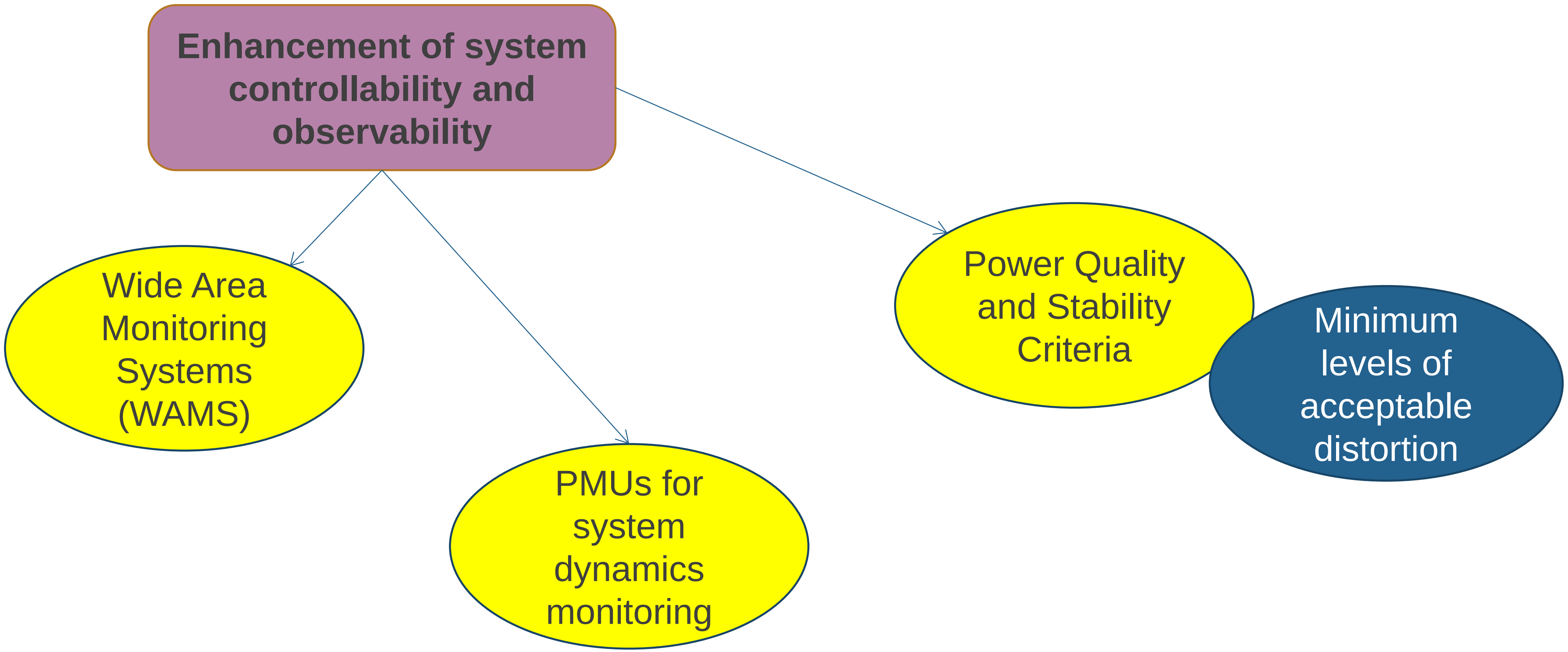
Roadmap towards PE-Dominated Power Systems (incl. HVDC)

Enhancement of system stability → Grid Forming Control

- The control should operate in a stable manner even without the presence of conventional generation units (grid with 100% renewables)
- The control-scheme should provide a synchronization effect to the system
- The control scheme should not be affected by the presence grid resonance neither affect the shape of grid resonance
- The control scheme shall provide fast reactive current injection during faults limited to the maximum current capacity that the power electronic switches are capable to withstand



Roadmap towards PE-Dominated Power Systems (incl. HVDC)



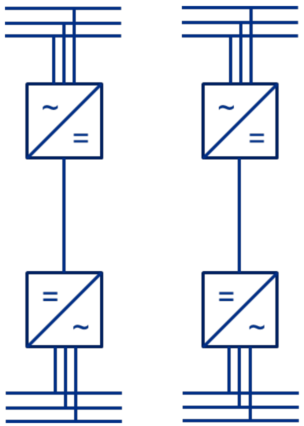
Roadmap towards PE-Dominated Power Systems (incl. HVDC)

Enhancement of Flexibilisation

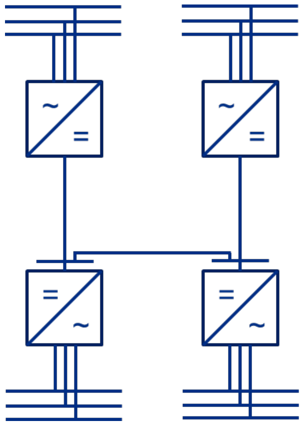
HVDC systems offer required flexibility for large scale integration of PEIG and grid forming control

HVDC systems can improve the overall AC/DC grid operation

HVDC systems can contribute to grid stabilization



Today: Single Point-to-point connections



Multiterminal Systems

Source:
PEI, European grid vision

DC grids as a backbone system for AC?

Roadmap towards PE-Dominated Power Systems (incl. HVDC)

Tools and advanced models

The dynamic security assessment of power electronic dominated networks will require both for accurate and computationally efficient models

The complexity of HVDC systems and PEIG in the grid requires for advanced modelling methodologies

The data exchange between TSOs and a common library of advanced models will enable effective network studies both regional as well as on a pan-European level

Roadmap towards PE-Dominated Power Systems (incl. HVDC)

Enhancement of Coordination

TSOs require control models of PEIG units and HVDC due to analysis of their behaviour in the entire system.

Need for standardized interfaces for vendor models.

Summary and Conclusion

- The characteristic of generation has been changing due to the massive integration of PEIG. The operational challenges due to the high penetration of PEIG are identified
- On the long term the power system will be able to accommodate a high level of PEIG up to 100% and will migrate from the traditional conventional generation based AC system to a hybrid AC/DC system
- HVDC interconnectors and may FACTs introduce a higher level of control possibilities, which can be used to enhance system security of supply
- In addition, the utilisation of novel control concepts to effectively use the technologies available will have a significant impact on how to operate the electrical energy system
- In order to cope with all the challenges, innovation, research and development in the electrical energy business is crucial (interoperability and demonstration will become more important)
- International and multilateral developments and demonstrations are essential to achieve a secure and sound socio-economic system operation

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