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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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

Ratio of PE on total installed capacity by 2030 (based on the TYNDP scenarios)

- Continental Europe
- Nordic
- GB
- IE-NI
- Baltic

Ratio in DG Scenario
Ratio in ST Scenario

New HVDC transmission capacity by 2030

- New HVDC links
- New DC connected wind

Year:
2018 2020 2022 2024 2026 2028 2030

GW:
0 10 20 30 40 50 60 70
Why PEIG is different from conventional generation?

Non-linear control dependent generation modules

Prime mover is generally decoupled from the grid through the power electronic interface (e.g. wind rotors)

Power Electronic Interfaced Generators (PEIG)

Currently: Need for stable grid voltage or a minimum short circuit level

Limited Over-loading Capability

Might contain the possibility to store or release energy
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

- Frequency stability challenges
- Voltage stability challenges
- Operation Challenges
- Voltage Formation
- Protection malfunction
- Control Interactions (Sub-synchronous, harmonic stability)
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.
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.
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.
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**
- **Observability**
- **Controllability**

**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)

Enhancement of system stability

Long-term
- Synthetic Inertia
- Adaptive Protection Schemes
- Grid Forming Control
- Advanced use of HVDC
- Storage

Short-term
- Grid Connection Codes
- Mitigation Measures
- Synchronous Condensers
- Ancillary Services
The control scheme should provide a synchronization effect to the system.

The control scheme should not be affected by the presence of 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.

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)
Enhancement of system controllability and observability

Wide Area Monitoring Systems (WAMS)

PMUs for system dynamics monitoring

Power Quality and Stability Criteria

Minimum levels of acceptable distortion

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

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

Today: Single Point-to-point connections

Multiterminal Systems

DC grids as a backbone system for AC?

Source: PEI, European grid vision
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.
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.
THANK YOU FOR
YOUR ATTENTION

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