Trends in Grid Integration of Offshore & Onshore Wind

Virtual Wind Workshop

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Agenda

Introduction – Grid integration of OF & ON wind: Two sides of the same coin

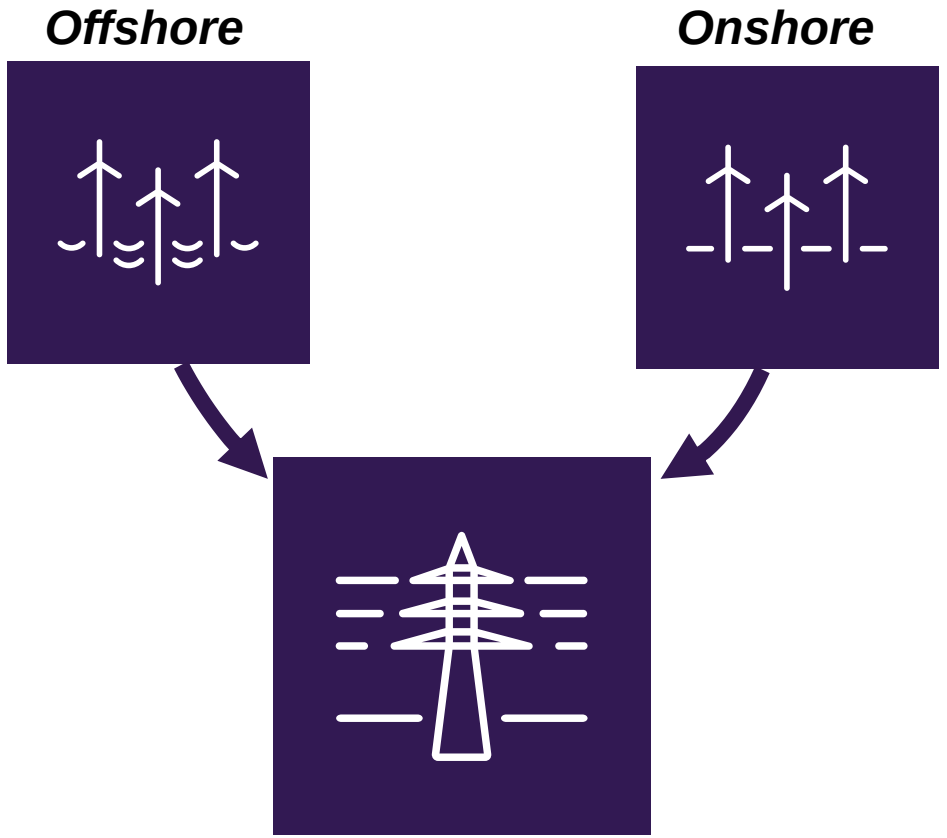
Decisive project factors, drivers for the evolution of the electrical infrastructure of a wind power plant so far:

LCOE / CAPEX Race		
Reliability		
OPEX Optimization		
Dealing with increasing project & WTG size		

Low relevance

Moderate relevance

High relevance



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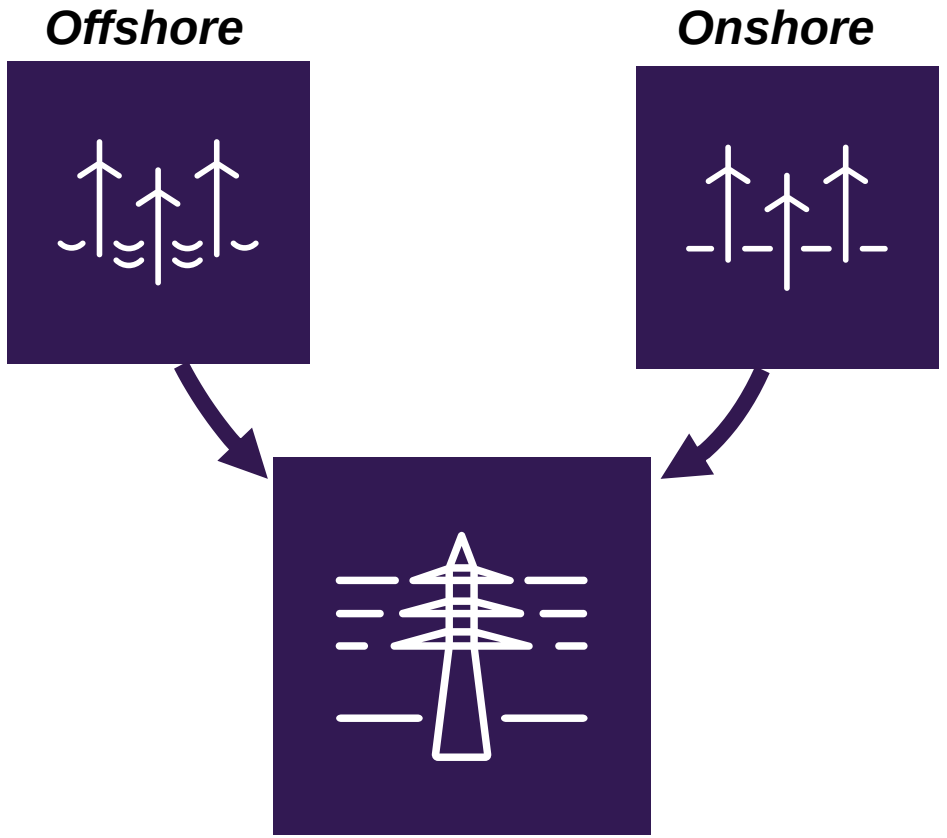

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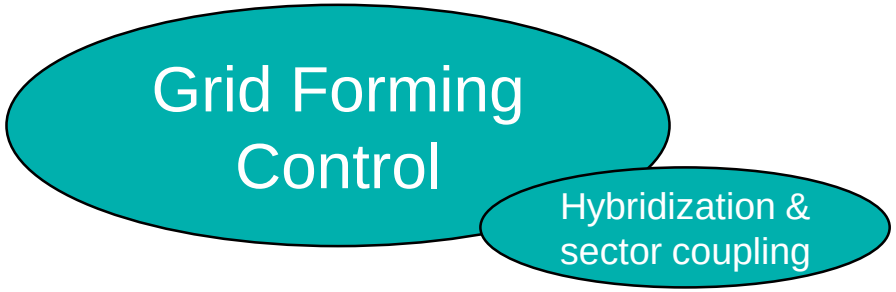
Focus of this presentation:



How are they linked to the factors on the left?

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Grid forming control: Fundamentals & Relevance

Why is control relevant to the electrical infrastructure of a wind power plant?

Why are we not hearing anything about HW? (SiC, GaN, semiconductors up to 10kV, complex converter topologies)

Maybe just another control structure that engineers came up with to keep them busy?

Extremely simplified definition of grid forming inverter:

Grid inverter operating as a voltage source with a low impedance, actively controlling the output voltage and frequency

Relevance of grid forming control for grid integration of wind power plants:

- **Enabler for weak grids & grids with high converter penetration**
  - Solving problems that grid following inverters have with high im
    grids
  - Saving costs through avoiding installation of additional eq
- **Offshore grid integration**
  - Enabler for cost-effective HVDC grid integration
  - Enabler for cost-effective islanded mode
- **Enabler for providing ancillary services**
- A prerequisite to reach 100% inverter based powe systems

Most points related to project costs & economics!

Grid forming control a relatively new topic for wind, but existing for a couple of decades, mostly for UPS in low power applications, and in the past 5 years in the portfolio of BESS providers for serving islanded offgrid projects in the up-to-10MW scale

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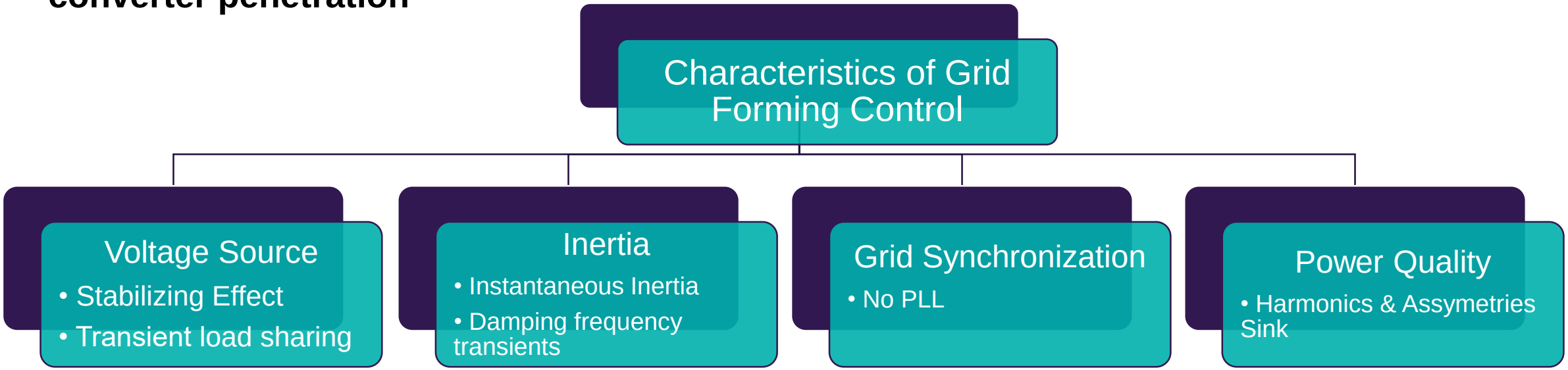
Grid Forming Control: Enabler for weak grids & grids with high converter penetration



- Typical grid following control has operational limits with weak grids / high impedance grids (low SCR), PLL prone to instability
  - Grid forming control can operate smoothly in lower SCR (not the only indicator for system strength, h… e shake of simplicity let‘s just stick to SCR)
- Project enabler for specific locations that will emerge due to higher RES penetration
  - New projects coming in this area in the next years (Both OF & ON)
- No need for additional HW such as synchronous condensers

Project enabler AND/OR cost relevant

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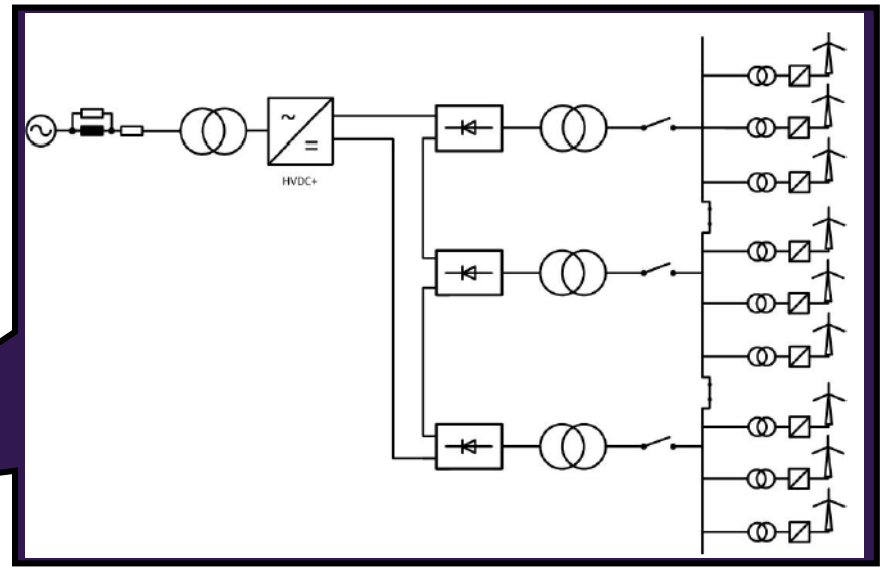
Grid Forming Control: Offshore grid integration

State of the art:

- HVAC: Standard array voltage up to **66kV**, higher voltages to come in the next years
- HVDC: An alternative for longer distances to shore



[1]

Grid forming control relevance:

- Overvoltage protection of HVDC station
- Enabler for cost-effective schemes, such as HVDC-DRU (Diode Rectifier Unit)
  - Starting-up the wind park not a straightforward task: Either with extra AC cable, or offshore storage
  - Such schemes are not yet established, mainly due to risks coupled with large scale implementation → LC[illegible]s intensifying, alternative connection schemes will emerge and establish to reduce costs

- **Cost-effective Islanded Mode**
  - Realization of grid connection can delay in offshore parks, island mode through grid forming con[illegible] useful to decrease size & costs of auxiliary power supplies
  - Enabler for islanded offshore grids
  - [For onshore: relevant for sites that have typhoon conditions]
  - Technical challenges: Operating point at very low generation level, challenging for pitch & potential mechanical impact on drivetrain

CAPEX & OPEX implications

[1] Seman et al, Modelling of the Diode-Rectifier based HVDC Transmission Solution for Large Offshore Wind Power Plants Grid Access 2016.

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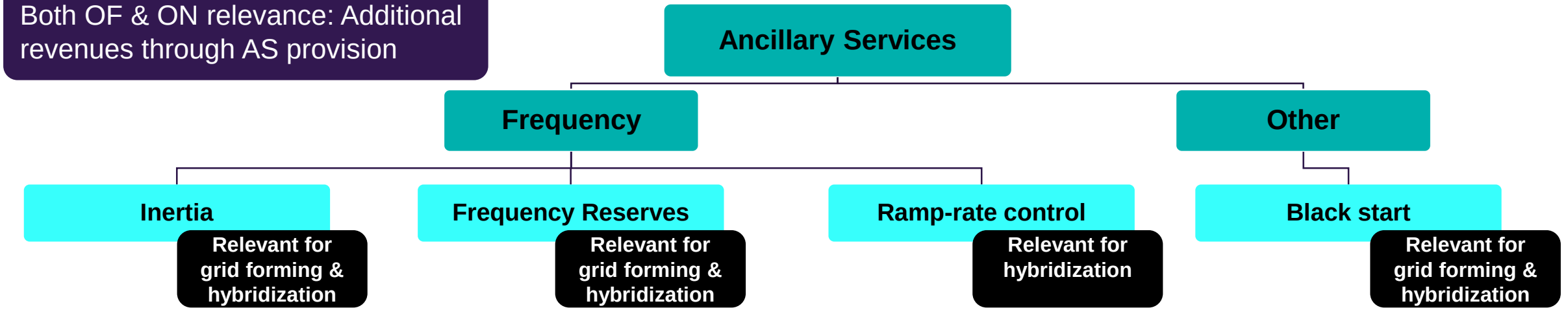
Grid Forming Control: Enabler for Ancillary Services

Both OF & ON relevance: Additional revenues through AS provision



Inertia:

- Grid Forming Inertia counteracting decommissioning synchronous generators, competing with synchronous condensers
- In the UK: Stability Pathfinder Phase 2 Tender considering also grid forming inertia
  - Ireland to follow

Black start:

- Trend in the next decade: Decentralized restoration plan based also on distribution level, m classical transmission-oriented central approaches
- Grid Forming wind to obtain primary or secondary roles in such decentralized restoration plans

Additional revenues
→ Optimization of project economics
Stacking of services to reduce costs for grid operators

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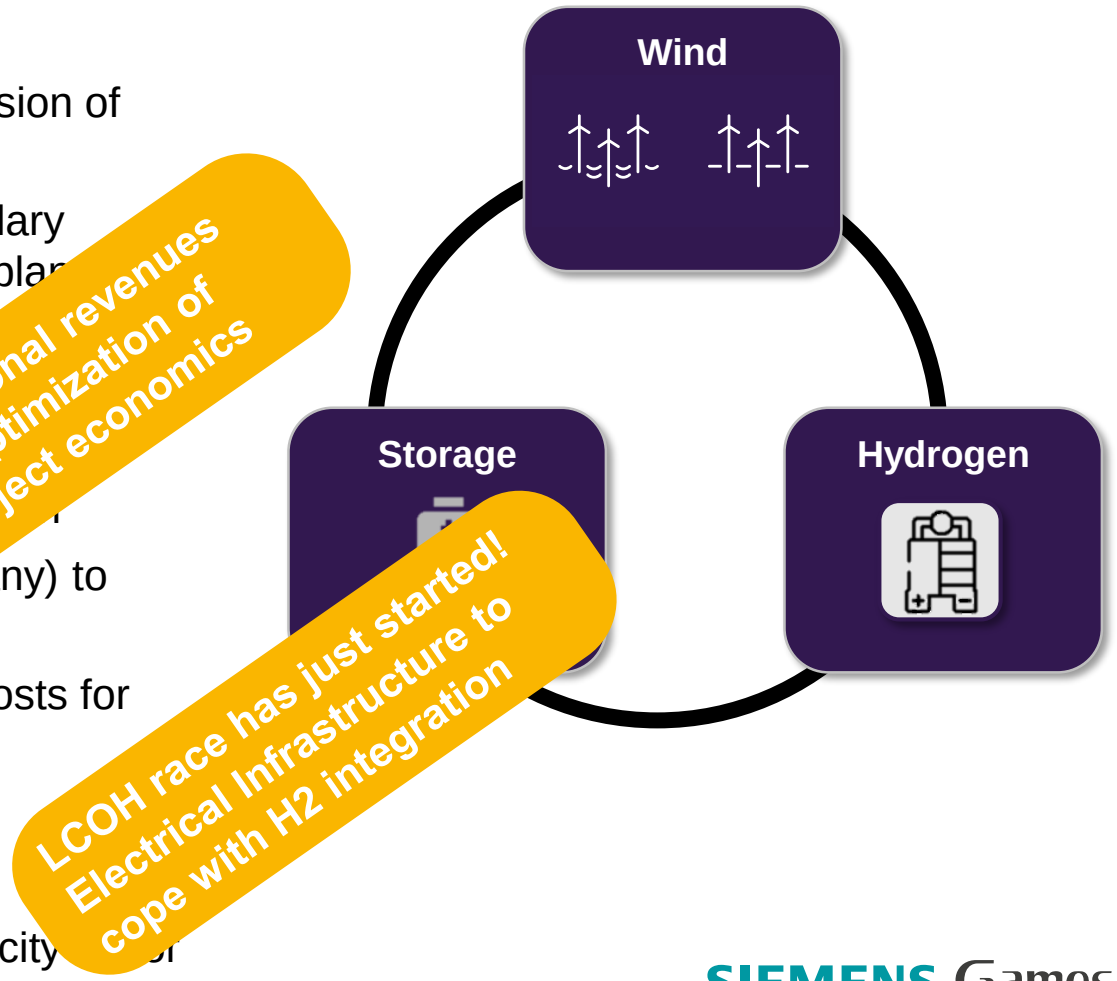
Hybridization & Sector Coupling

- Hybridization & sector coupling key elements for driving forward wind penetration
- Hybridization counteracting wind variability → reliable provision of ancillary services
  - Storage and accurate wind forecasting to enable ancillary services provision from wind based (or hybrid) power pla
  - Trend for frequency reserves from monthly contracts on a daily/hourly base → favorable conditions fo
- Different configurations depending on project & app requirements: Storage integration in wind turbine or
- Trend going from standalone battery projects (UK & Germany) to hybrid installations, exploring behind the meter utilizations
  - Stacking different services & consequently reducing costs for ancillary services for grid operators
- Great potential of coupling hydrogen production with wind
  - Different integration configurations
  - Offshore more appealing use case due to higher capacity



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Outlook

- Grid Forming inverters are inevitable, the question is how many do we need? → Depends on grid characteristics
- A point to consider: Reduced short circuit current → Modified protection relay settings and requirements of high voltage components, challenging the status-quo of protection mechanisms
- An essential step is to agree on exact specifications of behaviour of grid forming inverters as well as to define a suitable conformity testing process
  - VDE FNN Guideline Grid Forming behaviour of HVDC connected and DC-connected PPMs, published June 2020 → a first step
- Close collaboration between OEMs, Park operators & grid operators is needed to find the best economic fit and agree on specifications!

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