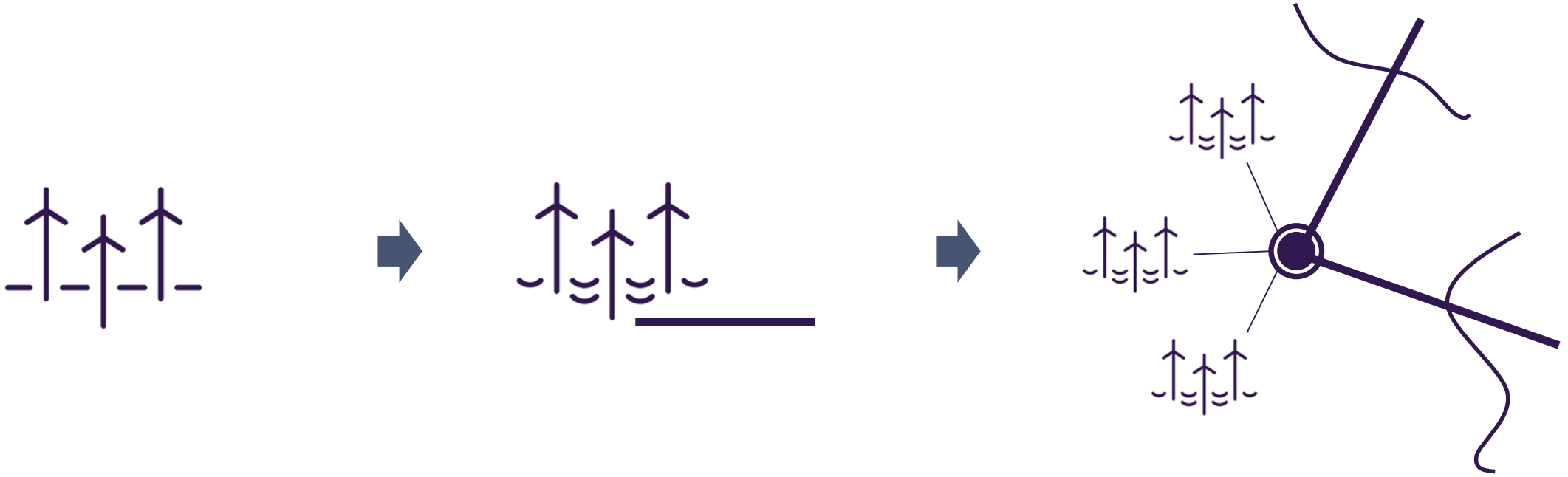
Professor Jacob Østergaard, DTU Wind and Energy Systems

IEA TCP Wind webinar 'Offshore Energy Hubs – Superpower of the Future', 2nd December 2022

Unique research challenges regarding energy islands

Next Frontier Development within Wind Energy



1980s

Onshore Wind Energy

2000s

Offshore Wind Energy

2030s

Offshore Energy Hubs

The islands will be first of its kind, involving a design from the scratch of an "extreme power system" with unprec

Many research questions:

- Stability
- Fault management
- Optimal grid topology
- Multi-vendor HVDC
- Grid forming converters
- Market design
- Optimal Power-to-X integration
- …

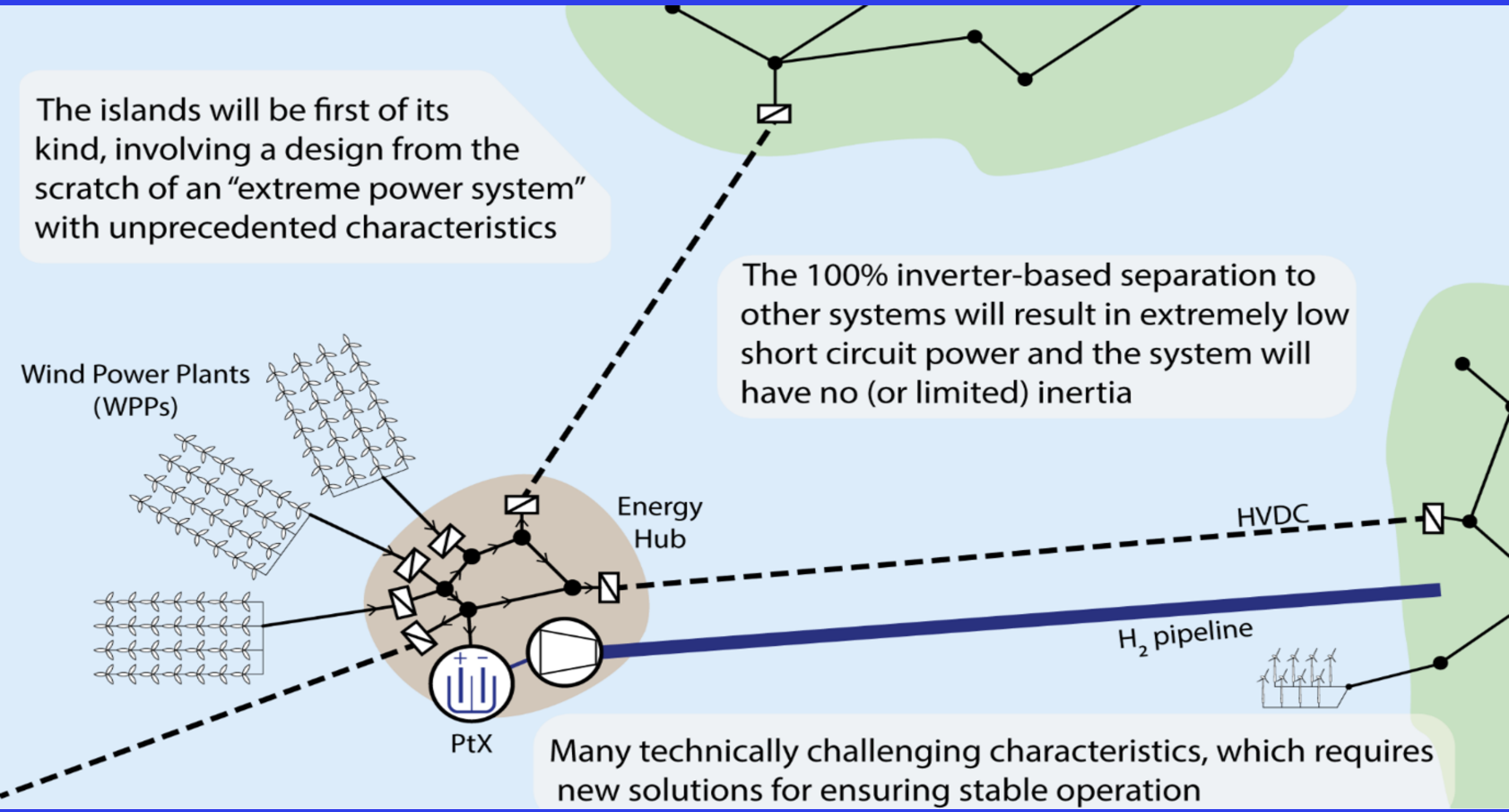
Cessna 172 Skyhawk

F-117 Nighthawk

Many technically challenging characteristics, which requires new solutions for ensuring stable operation

The islands will be first of its kind, involving a design from the scratch of an "extreme power system" with unprecedented characteristics

The 100% inverter-based separation to other systems will result in extremely low short circuit power and the system will have no (or limited) inertia

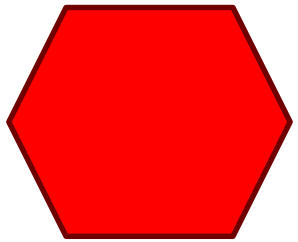


Many technically challenging characteristics, which requires new solutions for ensuring stable operation

Converter-based Power System

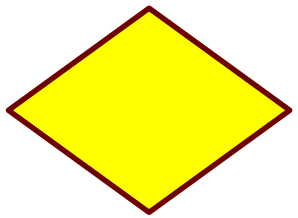
- Converters are devices that are (almost) fully defined by their control

…although fundamentally performing the same, functional differences due to control



Source: Hitachi Energy

Source: Siemens Energy



Source: GE Grid solutions

Converter-based Power System

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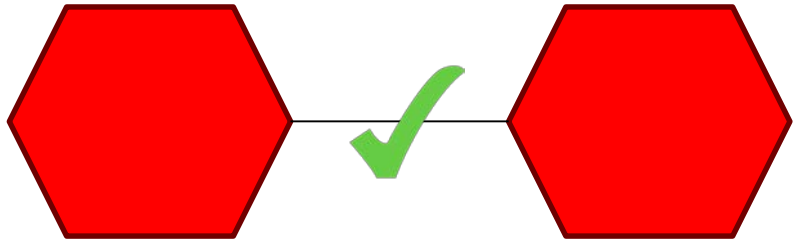
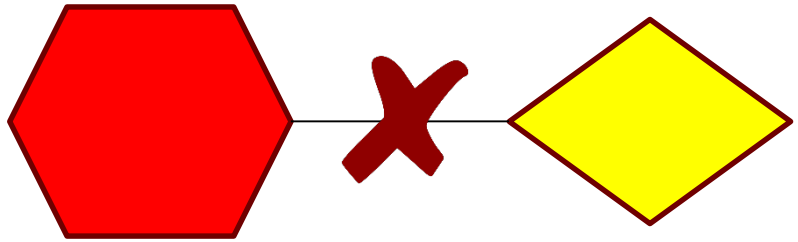
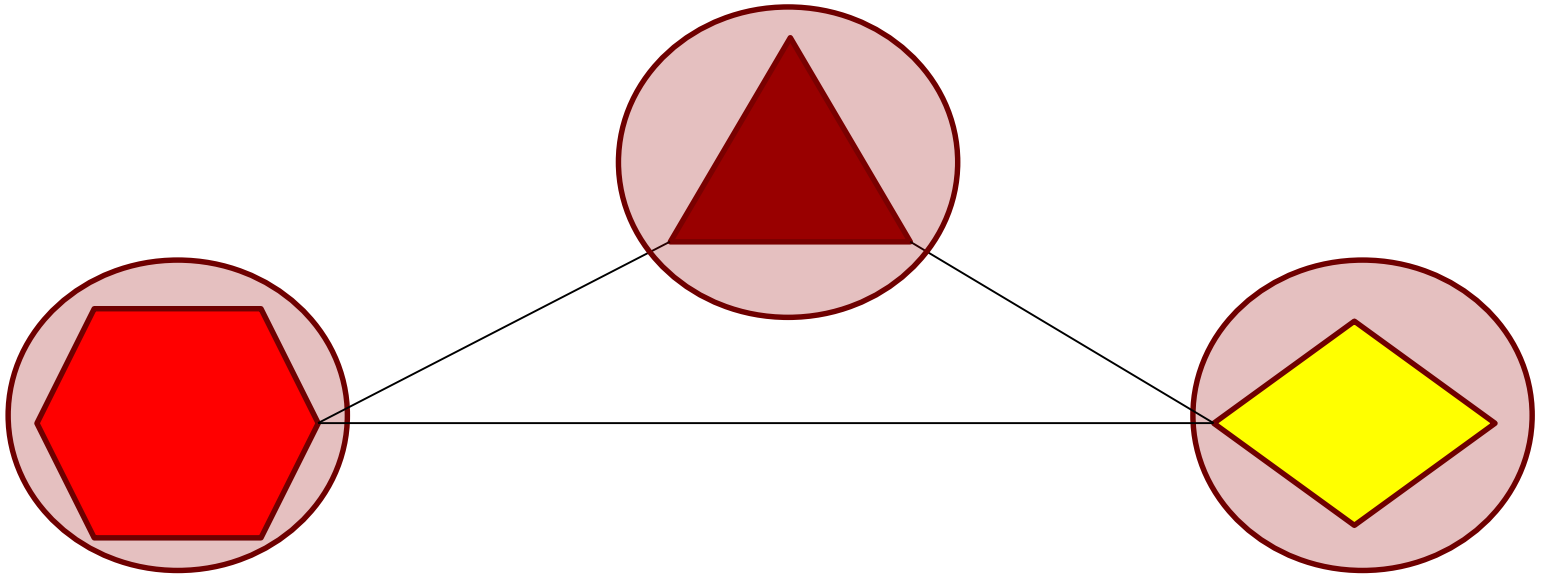
Single vendor



Multi vendor

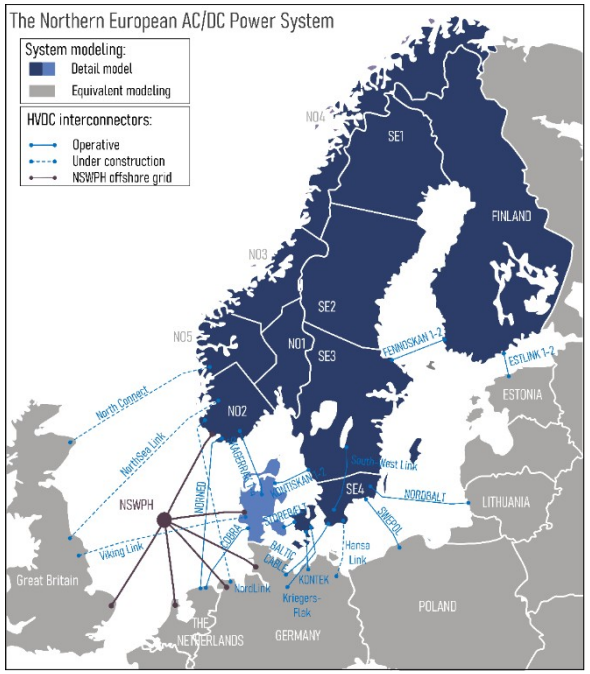


Multi-vendor and multi-terminal HVDC



System impact of offshore energy hubs

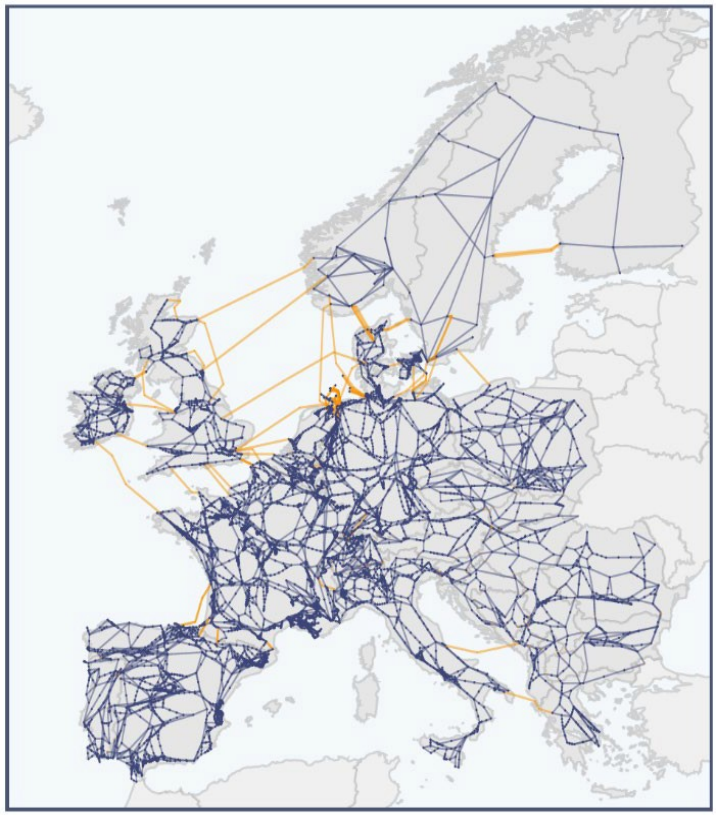
Dynamic Model of Northern European AC/DC System



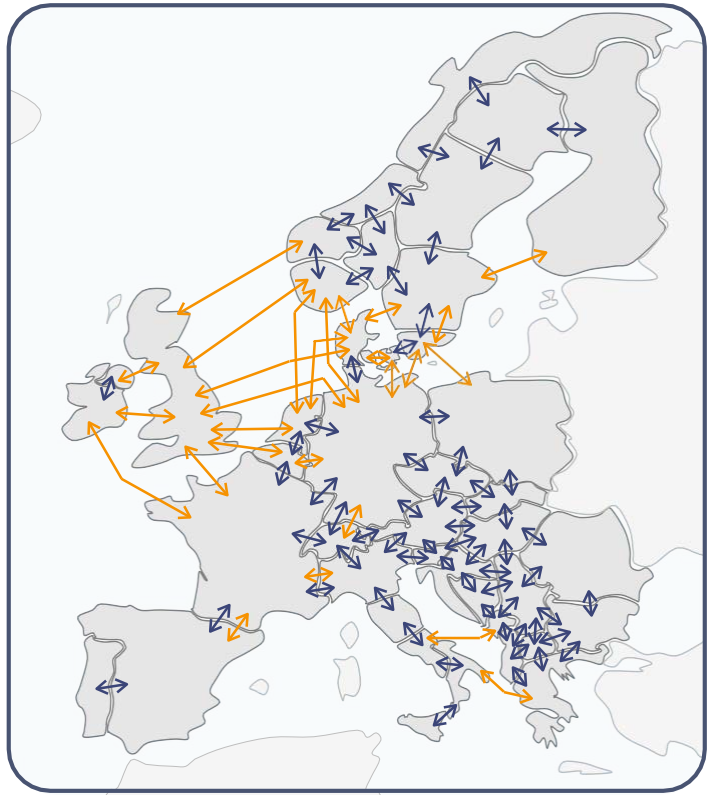
Online:
https://github.com/thematt199310/NorthEuropeanAC-DCPowerSystem-Model/

Frequency dynamics of the Northern European AC/DC power system: a look-ahead study, https://arxiv.org/pdf/2107.13890.pdf

European Grid: Static Security and Optimal Power Flow



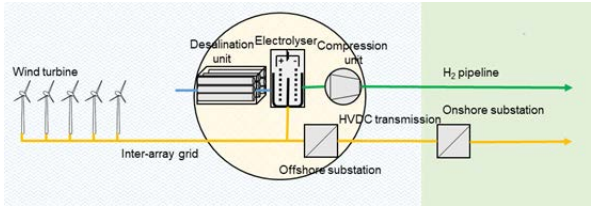
European market model

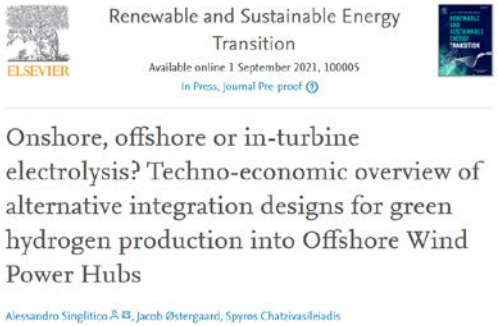


Online: https://github.com/antosat/European-Transmission-and-Market-Models/

A. Tosatto, X. Martínez-Beseler, J. Østergaard, P. Pinson, S. Chatzivasileiadis, North Sea Energy Islands: Impact on National Markets and Grids, available online: https://arxiv.org/abs/2103.17056

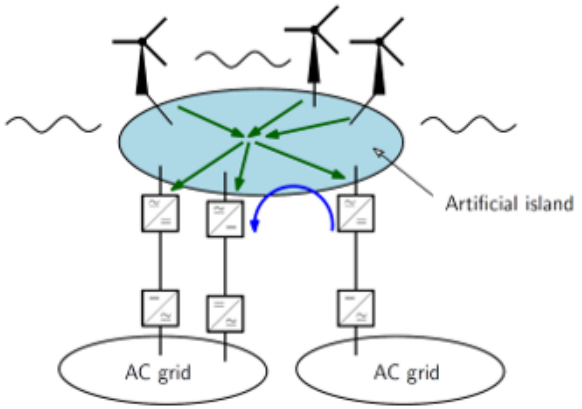
Energy Islands and P2X: where shall we place the electrolyzers?



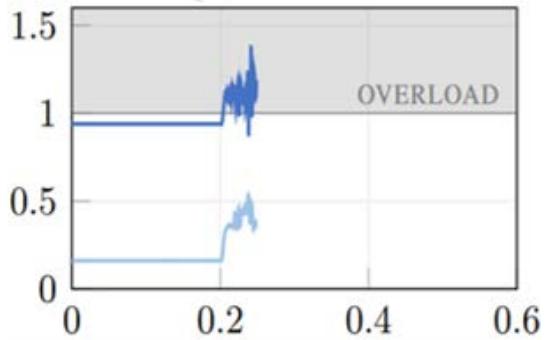


- **Offshore placement** of electrolyzer achieved the best results (compared to onshore and in-turbine placements), as it leads to:
  - **13% lower electricity cost** from Offshore Wind Power Hubs (cost of electricity delivered onshore)
  - **Cost-competitive hydrogen** (below 2.5 €/kg)

Zero Inertia Offshore Grids and N-1 Security

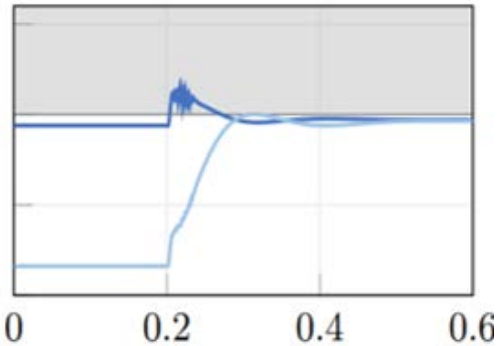


Fixed Freq. Droops of HVDC converters



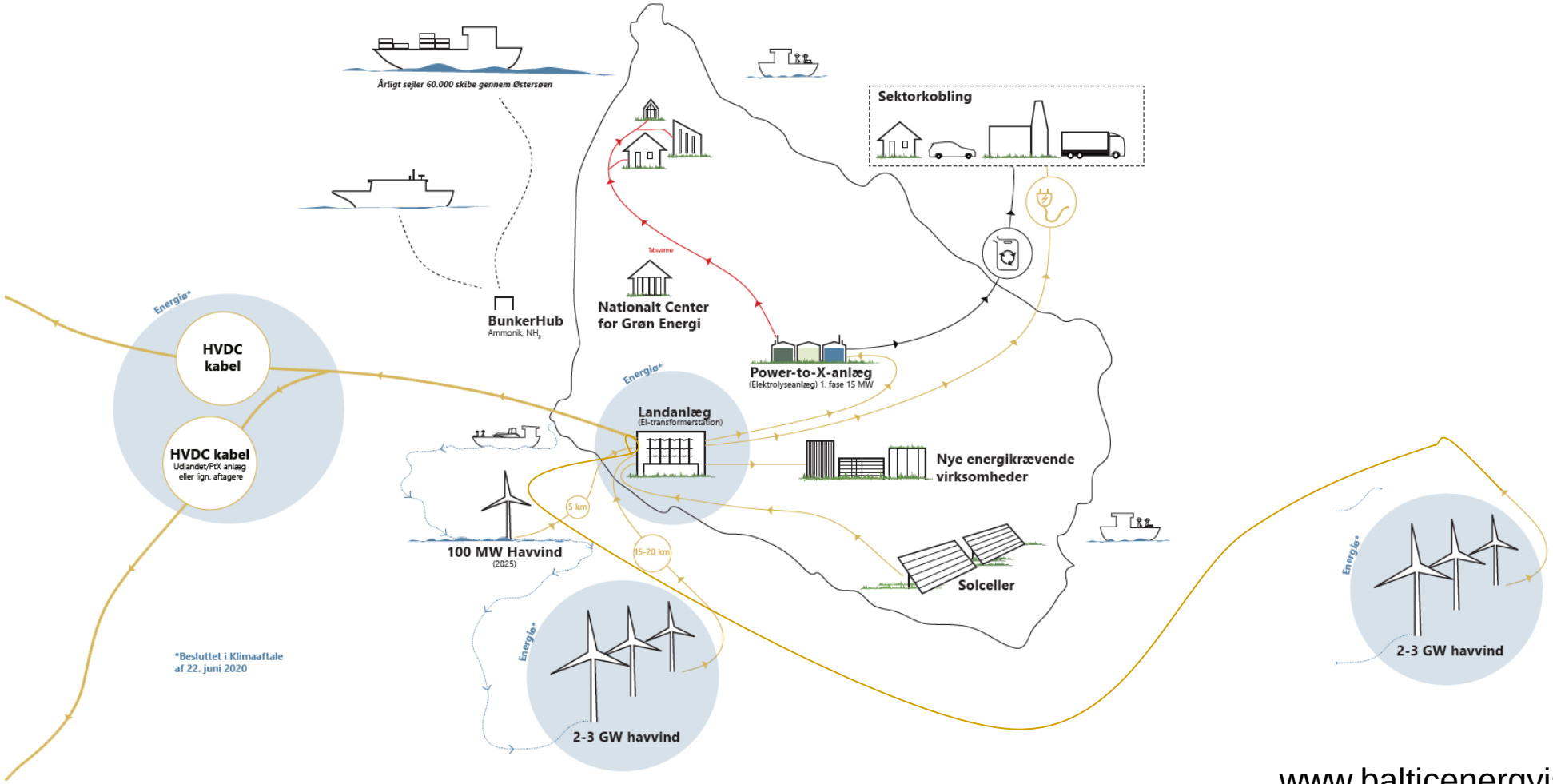
- Fixed droops → Converters operated close to their limits are saturated → System unstable
- Adaptive Droops → Avoid permanent saturation of the converters → System stable
- Adaptive droops → need for a master controller

Adaptive Freq. Droops



Papers, see: http://www.multi-dc.eu/publications/

Bornholm as test island for energy hub technology



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