WHEN TRUST MATTERS

Meshed HVDC grids

The next step for Offshore Wind in Europe

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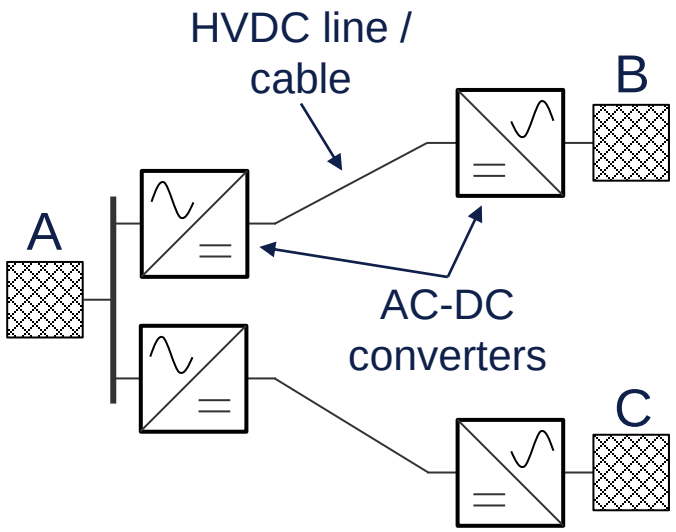
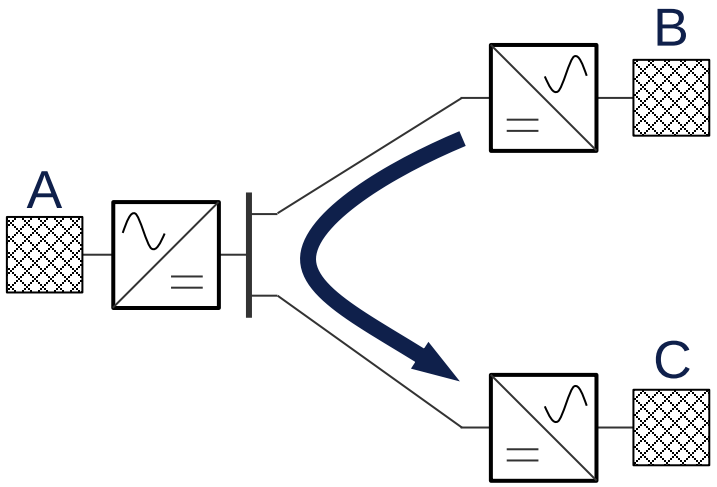
HVDC systems



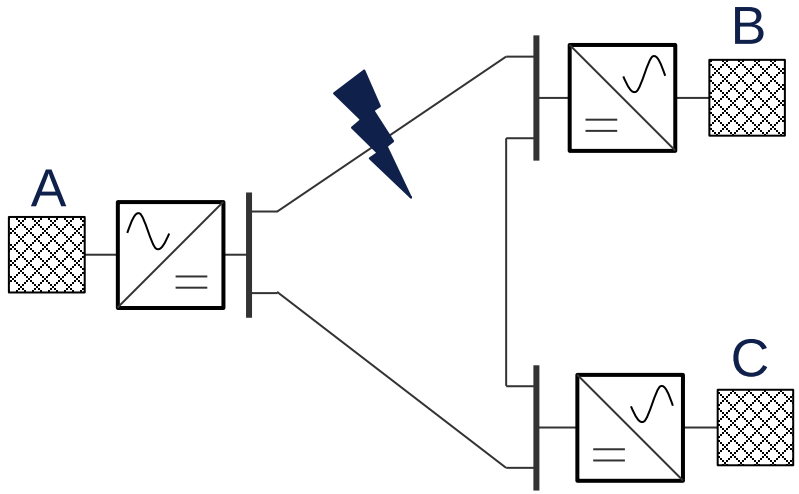
Point-point systems

- Bespoke projects
- Easier project development
  - Single vendor procurement
  - Single purpose
- Mature and widely applied



Radial multi-terminal system

- Multi-purpose
- Fewer converters
  - Lower cost
  - Lower footprint
  - Lower losses
- Requires compatibility



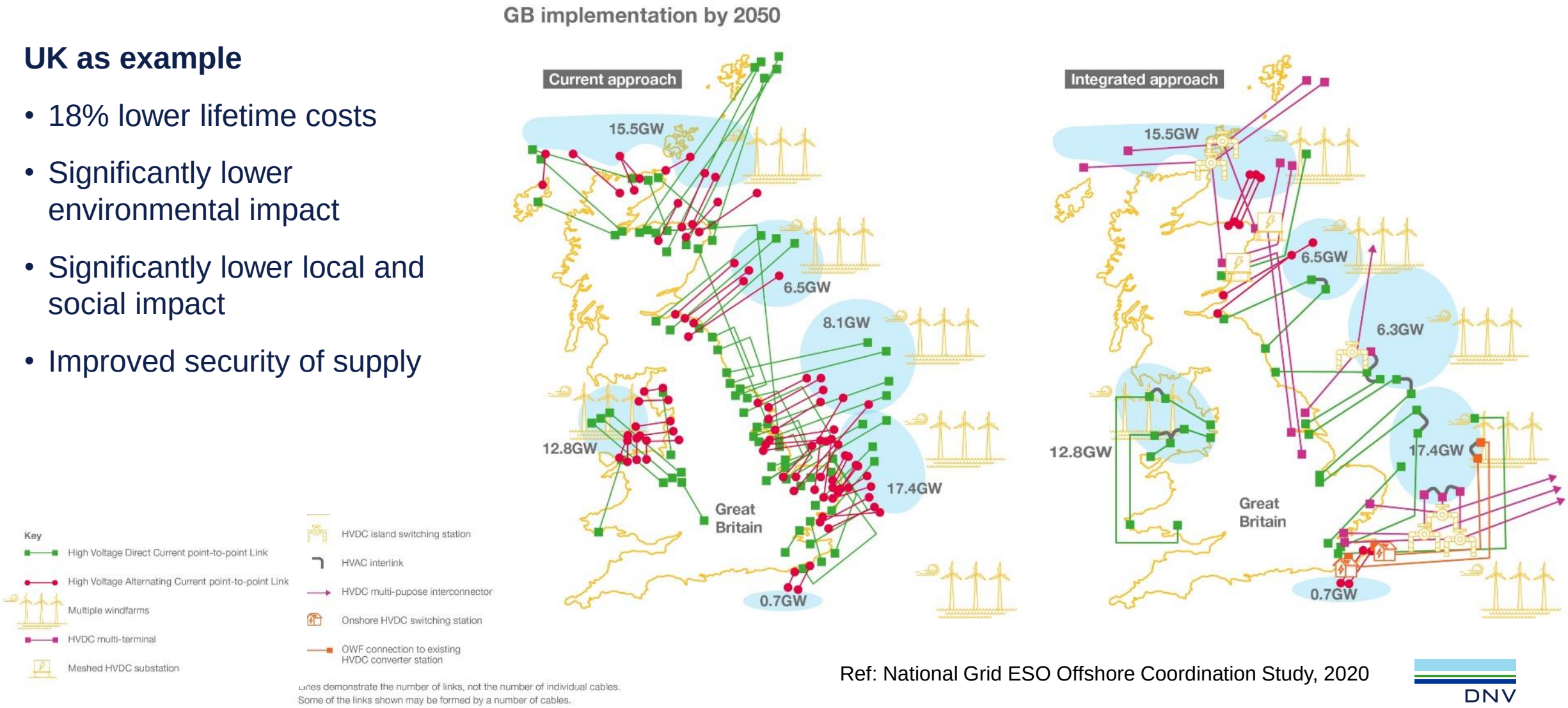
Meshed multi-terminal system

- Redundant paths
  - Increased availability
  - Reduced impact on AC grids
- Requires DC protection system

Multi-terminal HVDC grid benefits

UK as example

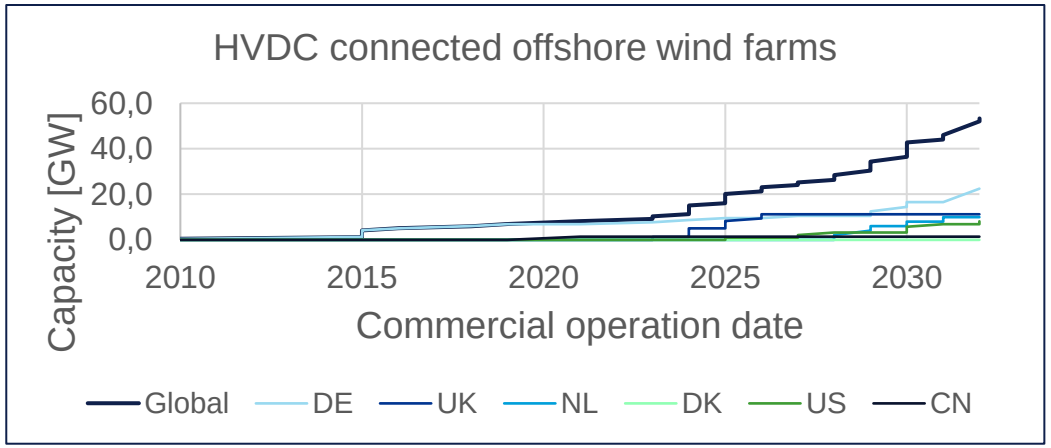
- 18% lower lifetime costs
- Significantly lower environmental impact
- Significantly lower local and social impact
- Improved security of supply

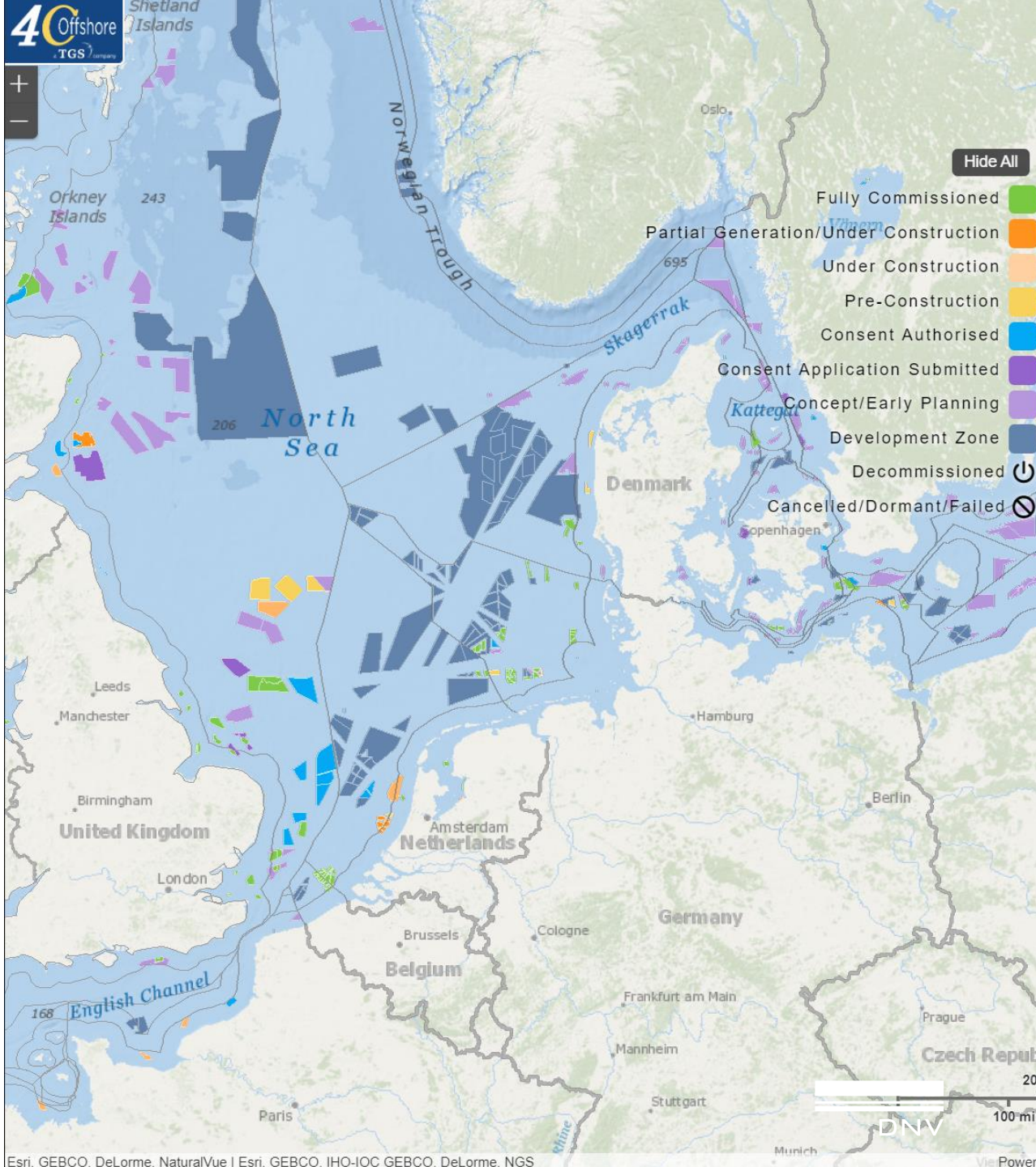


Ref: National Grid ESO Offshore Coordination Study, 2020

Offshore Wind

- Strong global growth expected
- First MT (radial) VSC-HVDC grids
- Multi-purpose HVDC infrastructure appearing
- Some countries leading the development – with “new” ones quickly coming up

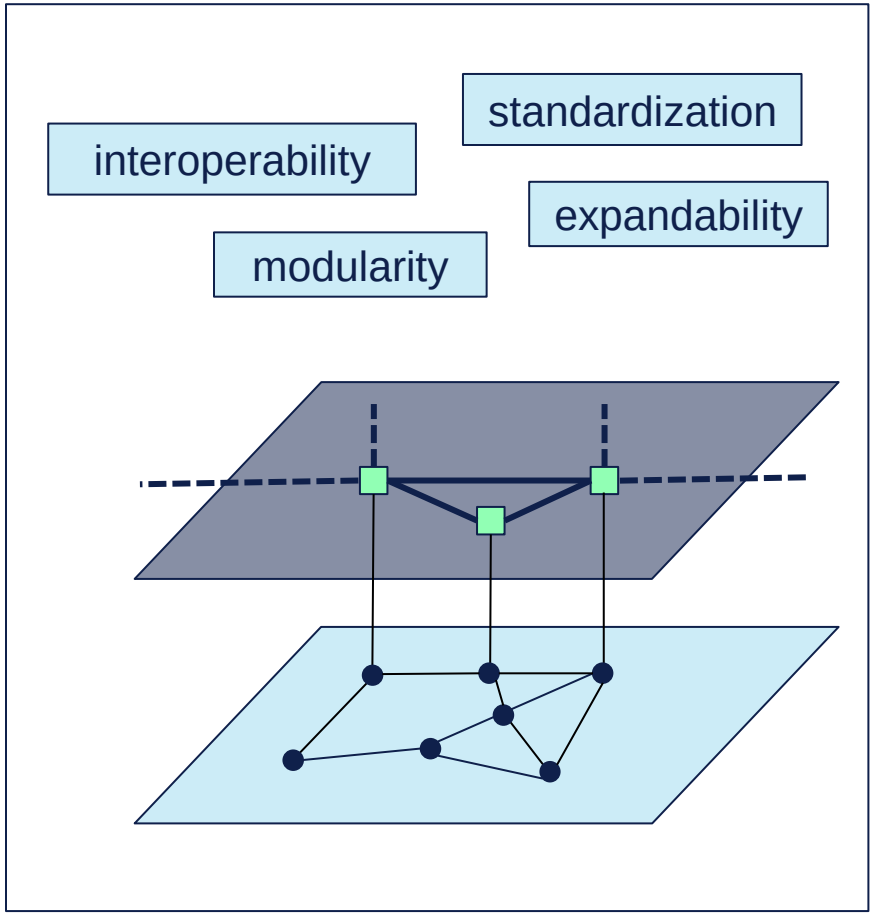




HVDC grids – Opportunities

- Benefits of HVDC grids:
  - Better use of wind resource
  - Better market integration
  - Relieve transmission grid congestion

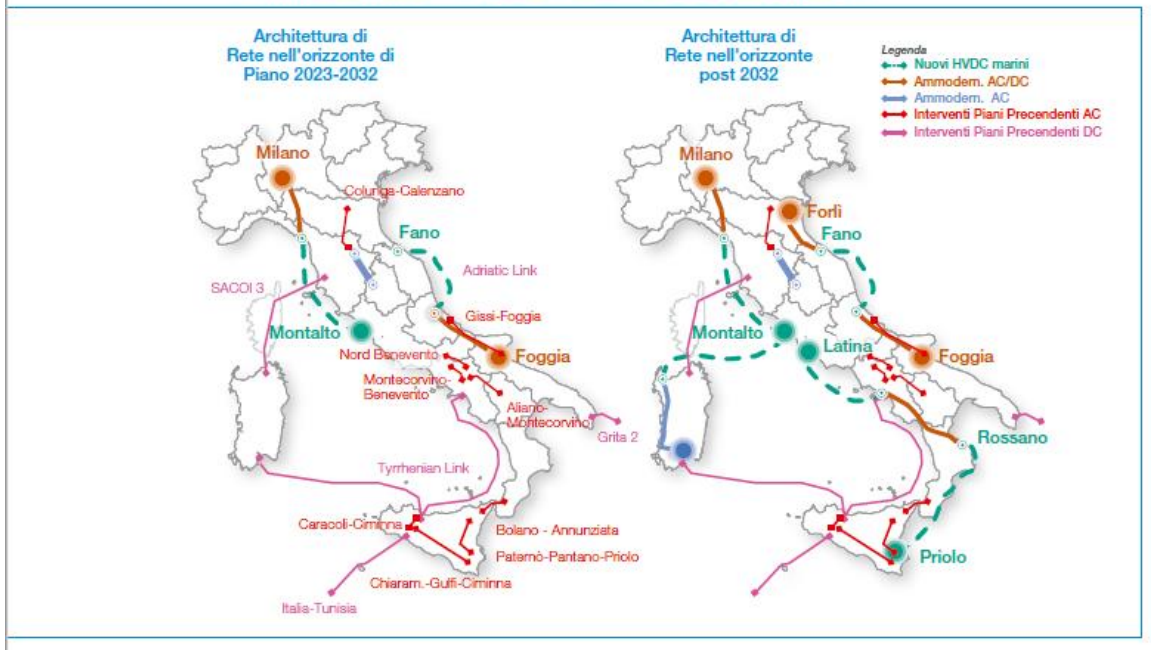
- Overlay DC grid as **backbone of the 2050 European grid**
  - Coordination to unlock **project synergies** and realize **societal benefits**
  - Standardisation to enable **technical compatibility** and interoperability
  - Integration with the existing AC grid



Example: Terna's Hypergrid

- New Development Plan of Italy's transmission grid unveiled in mid March
- Investment in the next 10 yrs up by +17% to a total of €21bn, of which €11bn for five HVDC backbones
- Power transmission capacity from south to north doubles from today's 16 GW to 30 GW
- Terna has connection requests for 300GW today
- The plan includes 500kV marine connections and extensive use of DCCBs by 2032

FIGURA 17 *Principali interventi di rete previsti nell'orizzonte di Piano e post 2032*



Source: Terna

Five new HVDC backbones combined with existing and already planned HVDC links (eg Thyrrenian link) create an overlay DC grid (Hypergrid)

HVDC grids – related collaborations

2014 2016 2018 2020 2022 2024 2026

Best Paths

Oct 2014-Sep 2018

Total budget: 62.8 M€
EC contribution: 35.5 M€

39 Partners from
11 European countries

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

Jan 2016 - Dec 2019

Total budget: 42M €

34 Partners from
11 European countries

HVDC grids feasibility proven

READY DC

Apr 2022 – Sep 2023

Total budget: 1M€
EC contribution: 1 M€

7 Partners

HVDC-WISE

Oct 2022 – Mar 2026

Total budget: 6.9 M€
EC contribution: 6.5 M€

14 Partners from
11 European countries

interOPERA
Enabling multi-vendor HVDC grids
October 2022

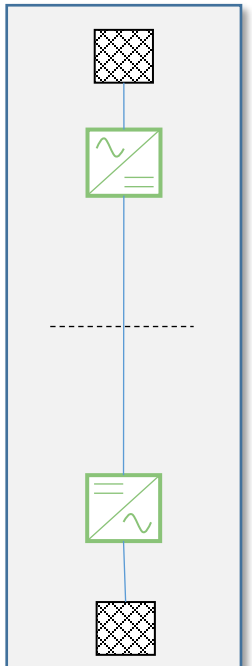
Jan 2023 – Apr 2027

Total budget: 69 M€
EC contribution: 50 M€

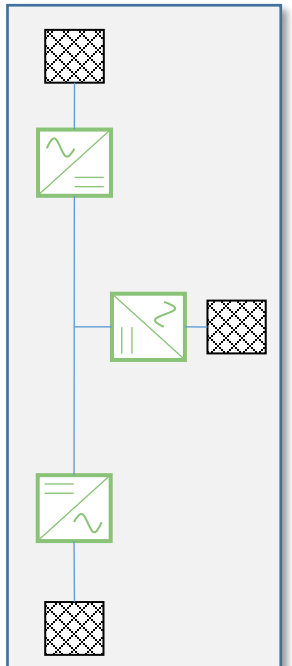
17 Partners

Pilot projects

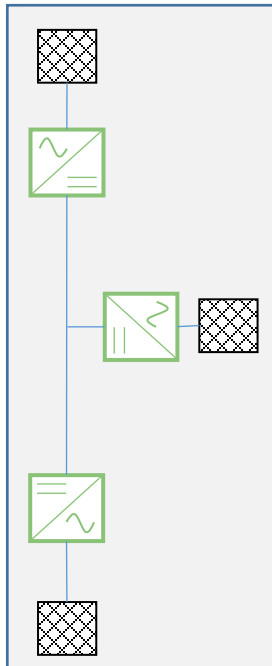
Full scale demonstrators of feasibility and benefits



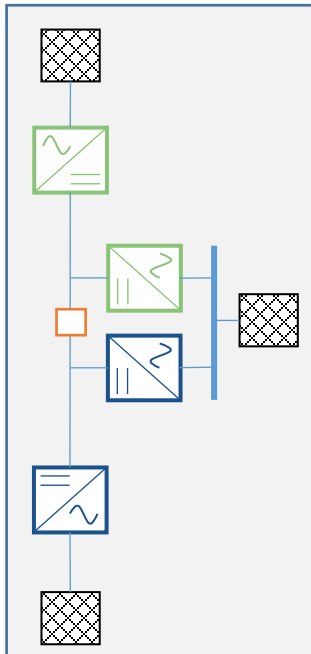
Standard
p2p
Half-bridge
MMC
single-
vendor



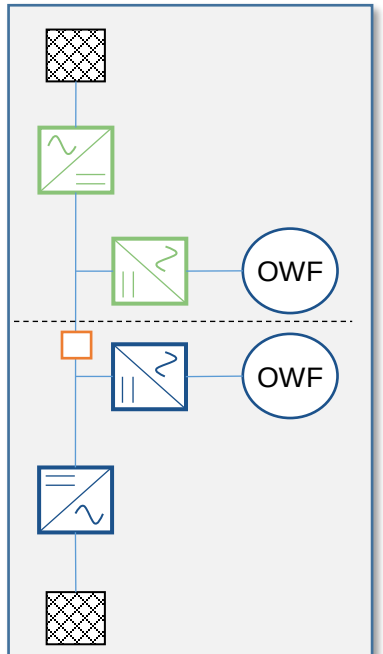
Radial MT
Half-bridge
MMC single-
vendor



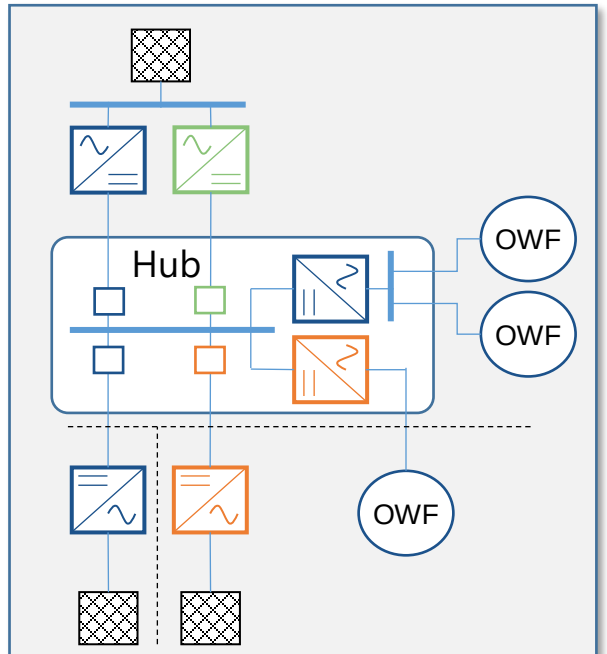
Radial MT
Full-bridge MMC
single-vendor



Radial MT
Half-bridge MMC
Multi-vendor
Onshore DCCB



Radial MT
Half-bridge MMC
Multi-vendor
Trans-national MT
Offshore DCCB



Radial MT
Half-bridge MMC Multi-vendor
Transnational MT
Offshore DCCBs

Pilot projects

Full scale demonstrators of feasibility and benefits

Radial multi terminal China

Meshed multi terminal China

Radial multi terminal Europe

HVDC GIS Europe

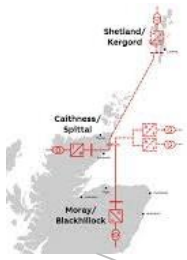
Full-bridge converters Europe

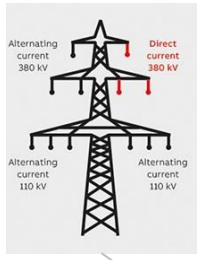
Standardization Modularization Coordination Europe

Meshed multi-terminal grids & islands Europe

Combination with hydrogen Europe

Offshore & multi-terminal HVDC US





EUROBAR

North Sea Wind Power Hub

2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033

160 kV 240 MW
Three-terminal radial
Na'nao system
China

200 kV 400 MW
Five-terminal radial
Zhoushan system
China

500 kV 3 GW
Five terminal meshed
Zhangbei system
China

320 kV 1200 MW
Three-terminal radial
CMS system,
Scotland, UK

320 kV 900 MW
HVDC Gas insulated switchgear
Borwin 5 & Dolwin 6 projects
Germany

380 kV 2 GW
Three-terminal FB
ULTRANET, Germany

2 GW 525 kV
HVDC Multi-terminal
readiness & HVDC GIS
IJmuiden Ver, Netherlands

525 kV 3x2 GW
Meshed offshore grid
Windstrom-Booster &
Heide HVDC hub
Germany

DNV

Energy Islands

Source: Danish Energy Agency

- NSWPH consortium (Energinet, Gasunie, TenneT) started working on offshore wind hubs in March 2017
- June 2020, decision to build 2 energy islands in DK – in the North Sea and in the Baltic Sea.
  - Bornholm energy island: capacity of 3 GW,
  - North Sea energy island: capacity of 3 GW in 2033, and 10 GW in the longer term.
- TritonLink will transfer offshore wind energy to DK and BE via two artificial energy islands
  - Studies are ongoing
  - Construction to start in 2026-27, energization in 2031-32

initial focus is on green electricity with additional production of green fuels such as hydrogen or ammonia in the future

Source: Energinet

Princess Elisabeth Island

Source: Elia

Summary

- Multi-terminal HVDC transmission grids:
  - have **significant benefits** over multiple point-point links
  - already exist → the **technology is ready**
  - are a **key enabler of the energy transition**
- **Pilot projects** needed to demonstrate technical feasibility and project benefits
- **Cooperation and collaboration** across all stakeholder levels needed to achieve:
  - Standardisation to enable **technical compatibility** and interoperability
  - Coordination to unlock **project synergies** and realize societal benefits

- Looking further: combine **offshore wind** and **hydrogen storage** in **energy island** concepts

Meshed HVDC grids

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