



Institut für
Hochspannungs-
technik

RWTHAACHEN
UNIVERSITY

Academic perspective on HVDC Development

Institute for High Voltage Technology - **RWTH Aachen University**

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Germany's "Energiewende"

Development of HVDC in Europe

Research activities

Addressing challenges in PROMOTioN

► Germany's "Energiewende"

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Addressing challenges in PROMOTioN

Goals of the new energy policy

Germany's "Energiewende"

- CO₂ abatement: At least 80-95% (1990...2050)
- 80% share of renewables in power generation mix (2050)
- Share of renewable energies in consumption of primary energy >50% (2050)
- Reduction of primary energy consumption by 50% (2008...2050)
- 50% share of renewable energies in power consumption (2030)
- Shut-down of all nuclear power plants (2011...2022)
- 35% share of renewable energy in power generation mix (2020)
- Grid expansion of 2800 km (2012...2020)



Classical transmission grid tasks

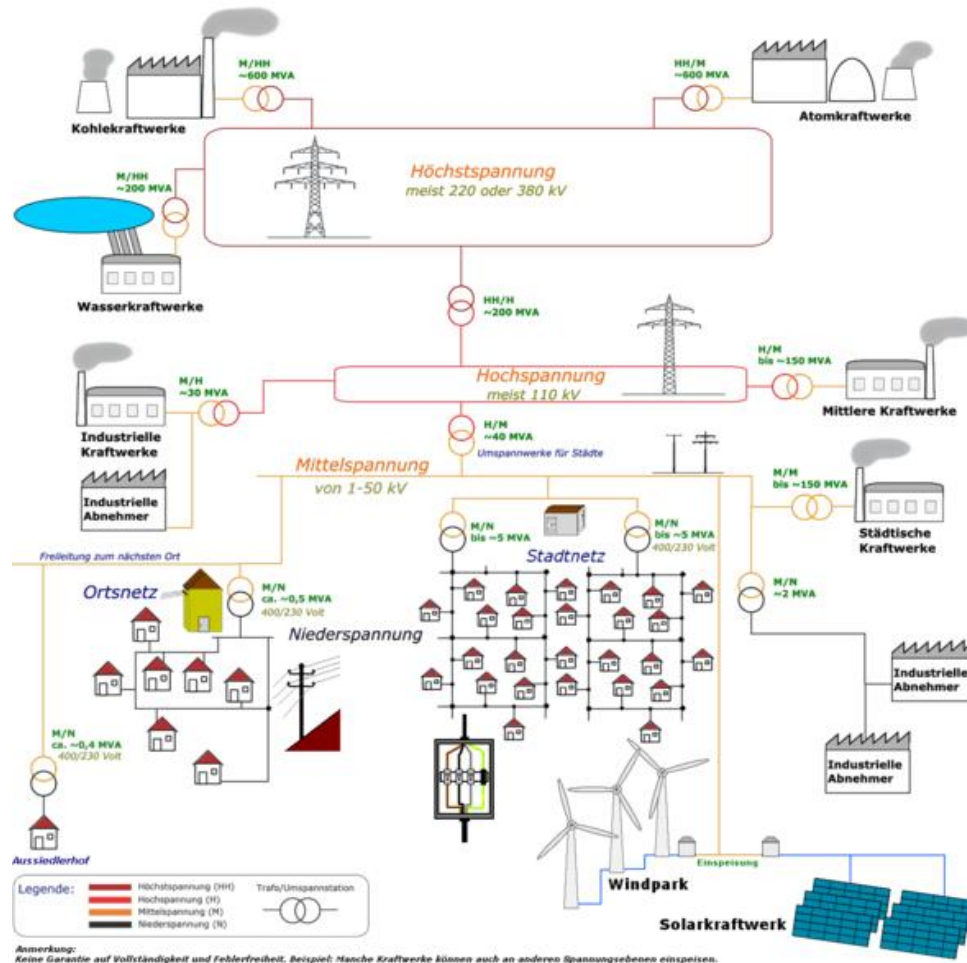
Germany's “Energiewende”

Transmission

- Transport of electrical energy
- Transport hierarchy
 - ↓ 380 kV AC (high voltage)
 - ↓ 110 kV AC
 - ↓ 10-20 kV AC (medium voltage)
 - ↓ 400 V AC (low voltage)

Grid Interconnection

- Compensation of regional load imbalances
- Optimization of regional cost-characteristics
- Increase of grid stability



Change of tasks within the high voltage transmission grid

Germany's "Energiewende"

Energiewende

Change of electrical power generation infrastructure

Local infeed based on fixed
schedules

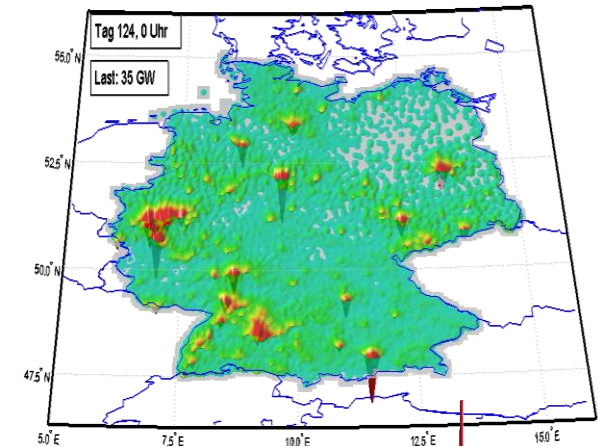


Remote infeed of volatile
energy sources

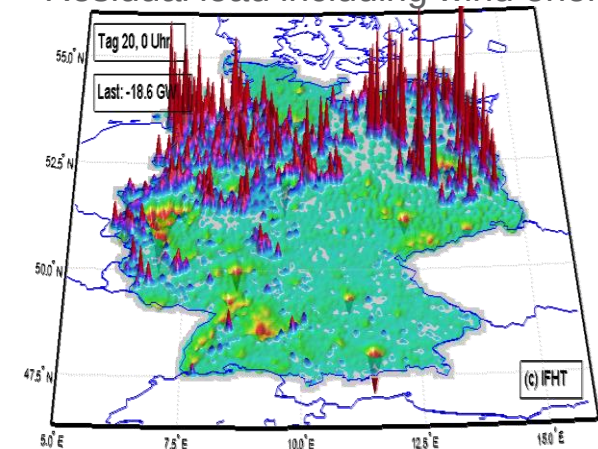
Introduction of European market for power trading

- New challenges for the transmission grid
 - Increasing infeed of volatile power generation units within medium voltage level causing load flow into the high voltage level
 - Changing load flows
 - Longer transmission distances of electrical energy
- Flexible grid extension strongly required

Residual load excluding wind energy



Residual load including wind energy



Grid Extension

Identification and evaluation of required extension measures

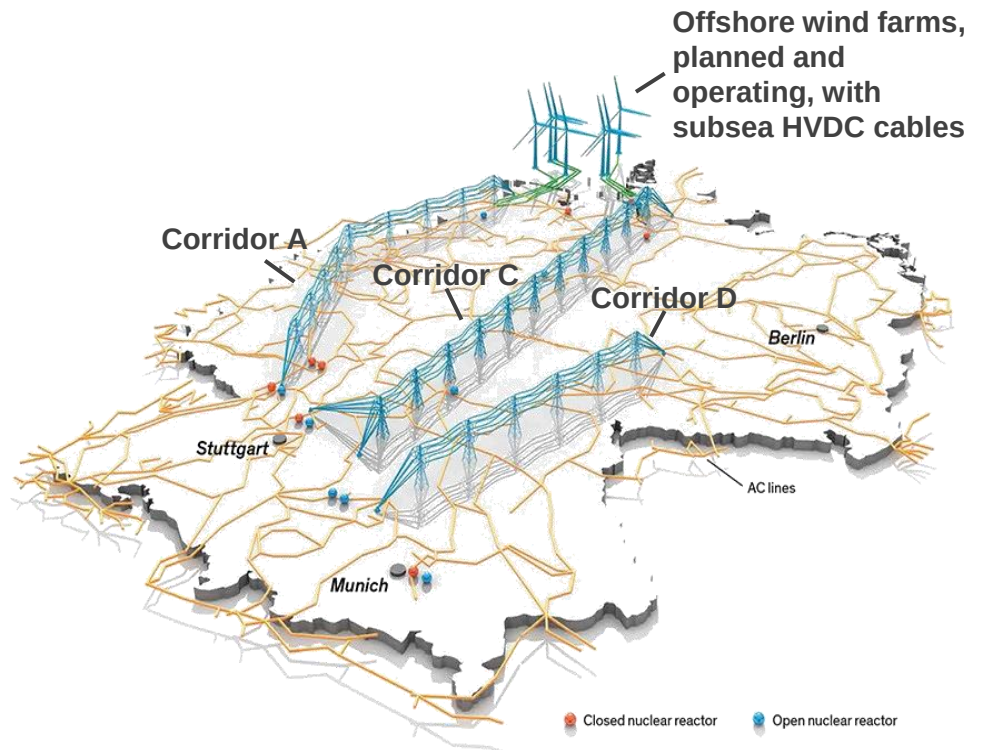


Germany
Grid Development Plan (GDP)



Identified need for extension within the next 10 years (23 Billion €)

- AC-side grid reinforcement and extension:
 - 5.000 km
- Introduction of HVDC corridors
 - 2.600 km



Grid extension

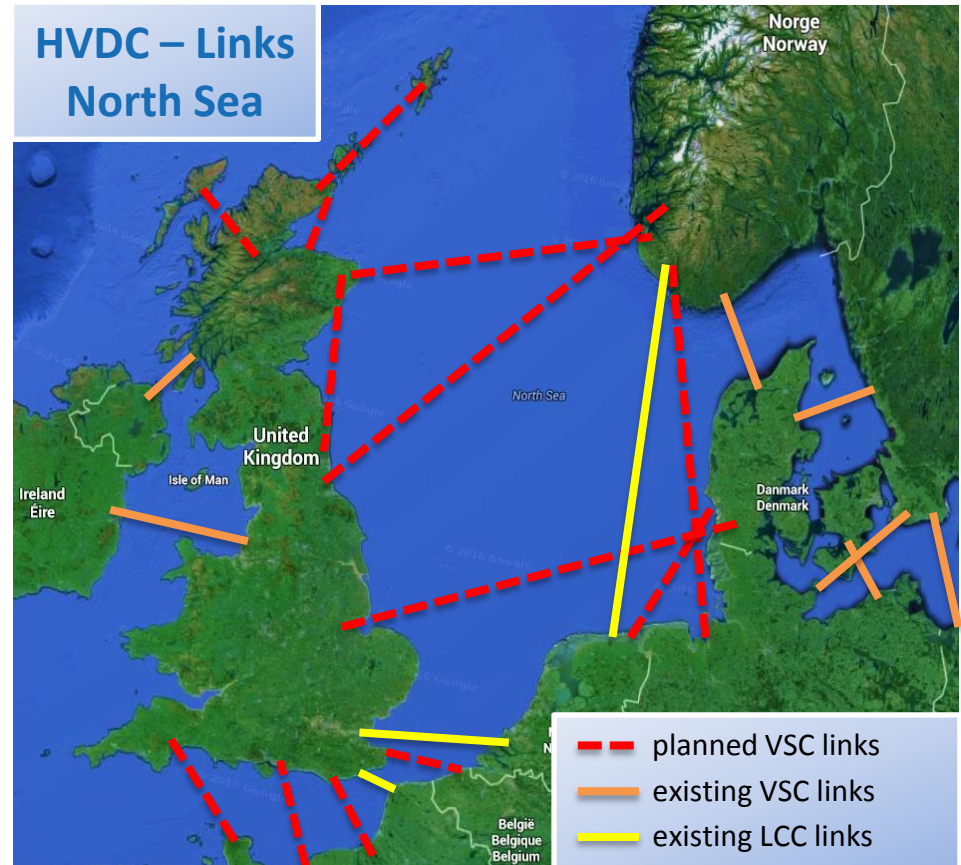
Identification and evaluation of required extension measures

Europe

Ten-Year Network Development Plan (TYNDP)

Identified need for extension within the next 10 years (150 Billion €)

- AC-side grid reinforcement and extension:
 - 48.000 km
- Introduction of HVDC corridors
 - 20.000 km



Germany's "Energiewende"

► Development of HVDC in Europe

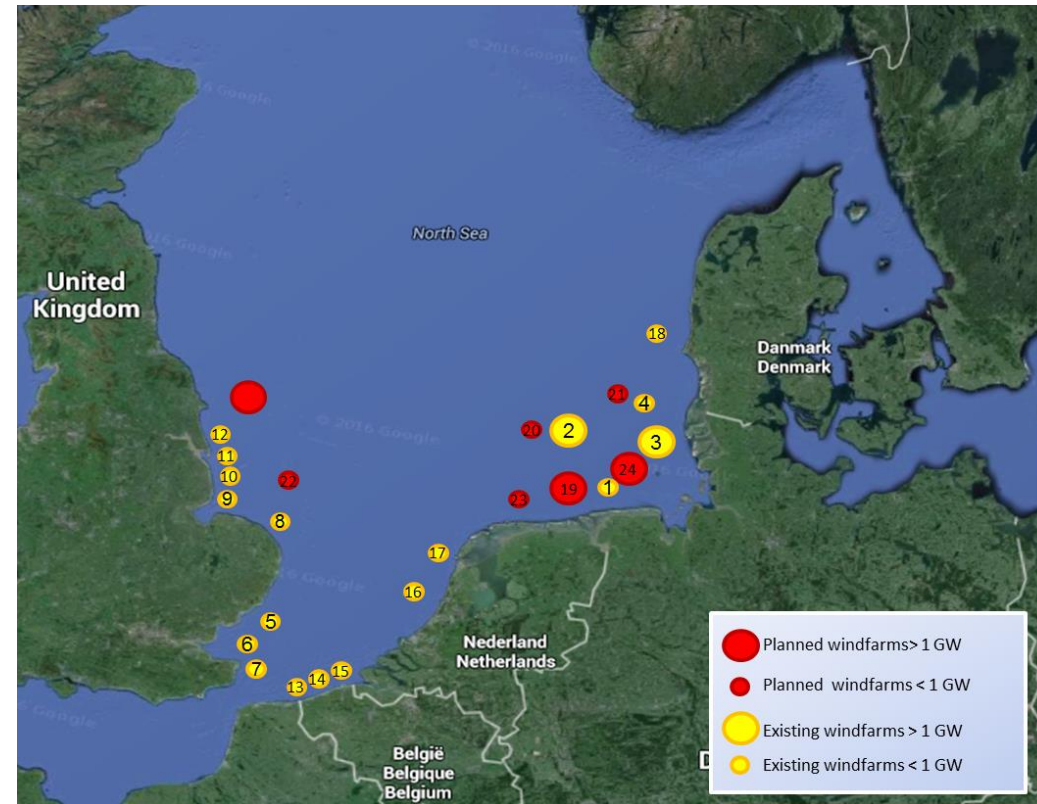
Research activities

Addressing challenges in PROMOTioN

Offshore wind parks in the North Sea

Development of HVDC in Europe

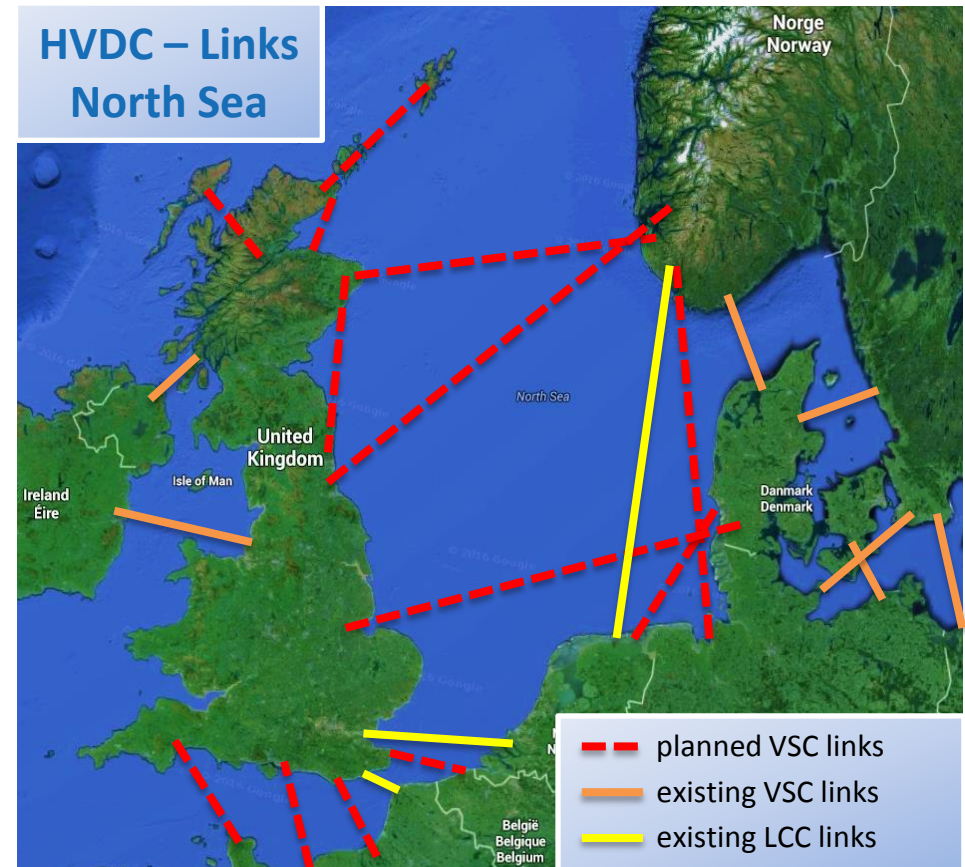
- High AC cable charging currents for long transmission distances (>60 km)
- Weak AC offshore grids
- Connection of offshore wind park cluster in the North Sea with HVDC technology is reasonable option



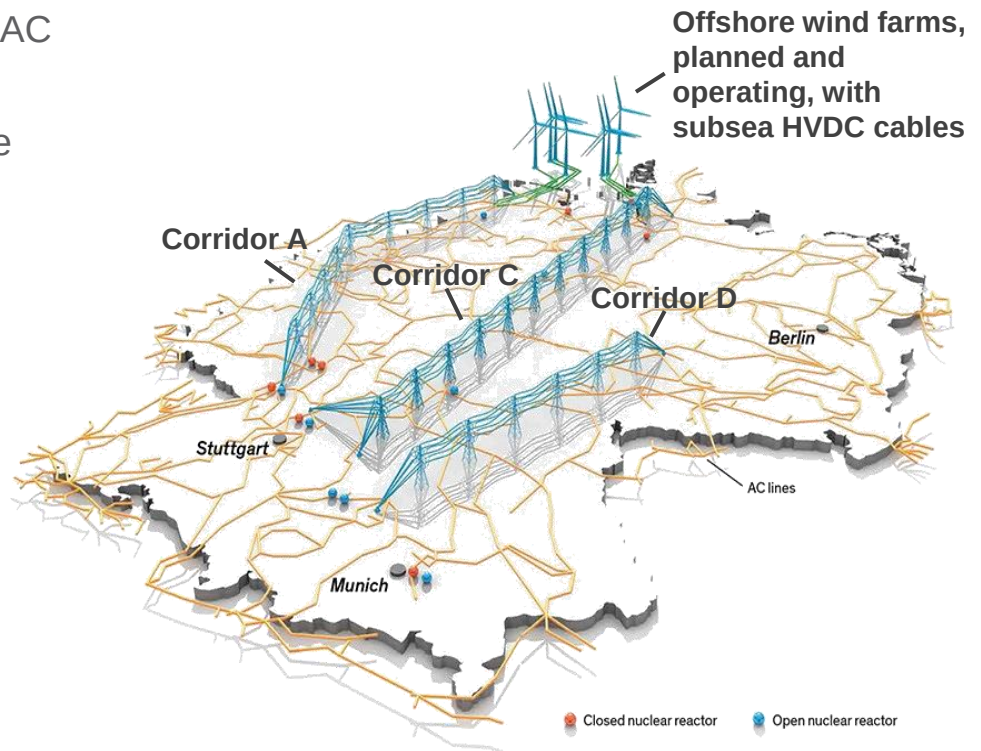
Offshore wind park connection with VSC

Development of HVDC in Europe

- Up to 230 km distance and up to 900 MW rated power at ± 320 kV
- Higher voltage levels expected
- Currently about 20 HVDC connections in planning or construction phase
 - Realization from 2015 to 2033



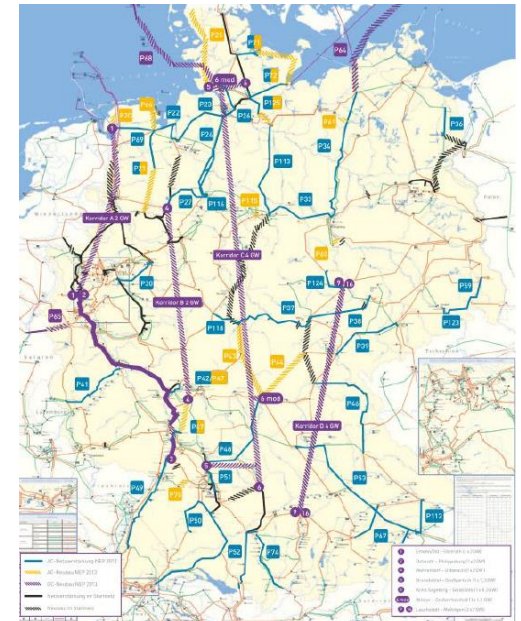
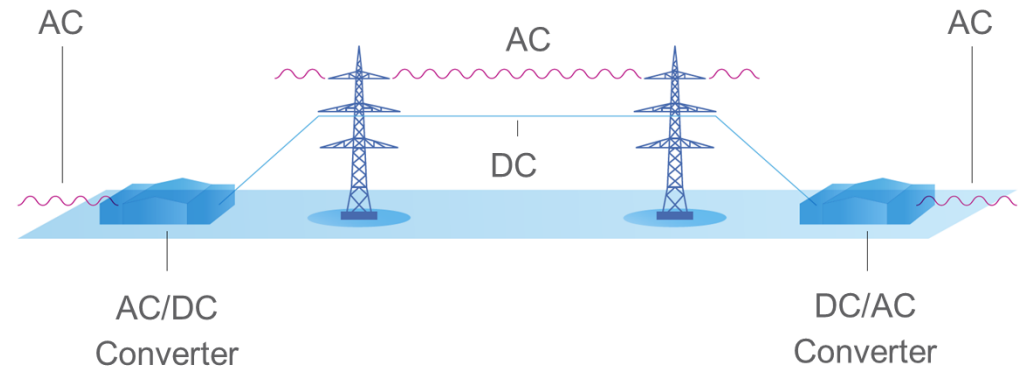
- Corridor A:
 - Three-terminal HVDC overhead line system
 - Partly realized as hybrid AC/DC transmission line (AC and DC systems on the same tower)
 - Modular multilevel Converter (MMC) with full bridge submodules (no DC breaker)
- Corridors C and D:
 - Technological realization still to be decided
 - Partial cabling or full cabling in discussion due to public resistance against overhead lines
- New or extended protection concepts required with respect to the imposed challenges



Corridor A: „Ultrahigh“

Development of HVDC in Europe

- Hybrid AC/DC corridor
 - Bipolar overhead line transmission
 - MMC with full bridge submodules
 - 320 km @ +/- 400 kV DC and 380 kV AC
 - Dedicated metallic return conductor
- Interconnection of West-Germany with South-Germany
 - West-Germany: Coal energy and high load centers
 - South-Germany: High loads and solar energy
- Next step: Extension to a three-terminal HVDC system interconnecting North-Germany
 - North-Germany: Wind energy



- Interconnection of remote power generation units with load centers
 - Efficient energy transmission over long distances (e.g. Offshore wind energy from northern to southern Germany)
 - Support of the existing AC transmission grid
 - Support of the AC transmission grid
 - Load flow control (in coordination with other actively controlled assets)
 - Control of power/ frequency
 - Stationary voltage support and reactive power compensation
 - Fault-Ride-Through with (dynamic) reactive power compensation
 - Black-Start capability
- HVDC is an integral part of the “Energiewende”

- First multiterminal system in China
- 5 Terminals with MMC half bridge converter
- In operation for over 400 days
- No DC breaker yet (installation to be finished in december 2016)
- Interruption on the AC side of DC converter



Germany's "Energiewende"

Development of HVDC in Europe

► Research activities

Addressing challenges in PROMOTioN

- Multi-terminal HVDC systems
 - Onshore (e.g. “Corridor A”)
 - Offshore (Northern Sea activities)
- Higher voltage levels possible utilizing new types of HVDC cables
 - Onshore (e.g. “Corridor C”)
 - Offshore (Northern Sea activities)
- Realization of upcoming HVDC projects
 - MMC full bridge technology (e.g. “Ultrahv”)
 - MMC half bridge and DC circuit breaker (e.g. multi-terminal extension)
- New fault management strategies required
 - Detection and localization
 - System recovery
- Existing demand for research in the field of HVDC control and protection

- How can multi-terminal systems can be protected with respect to selectivity?
- How will multi-terminal systems be controlled?
- What are constraints in the
 - operation of HVDC systems with partial underground cabling?
 - operation and fault handling of hybrid AC/DC overhead lines systems?
- Are DC/DC converters required for offshore application?
- Which technology requires which fault management strategy?
- Which extent of communication infrastructure is required?
- What has to be agreed on in terms of interoperability?
- How can a future HVDC offshore grid be realized? What are the first steps?

- RMS/EMT simulations of HVDC systems
- Real time simulation of HVDC grids
- Hardware testing of HVDC system components
- Hardware test benches offer required insight into control and protection of HVDC grids

- Industrial research projects
- Openly funded projects e.g. EU Research projects
 - TWENTIES
 - BestPaths
 - PROMOTioN

Germany's "Energiewende"

Development of HVDC in Europe

Research activities

► Addressing challenges in PROMOTioN

- Interoperability and Interaction

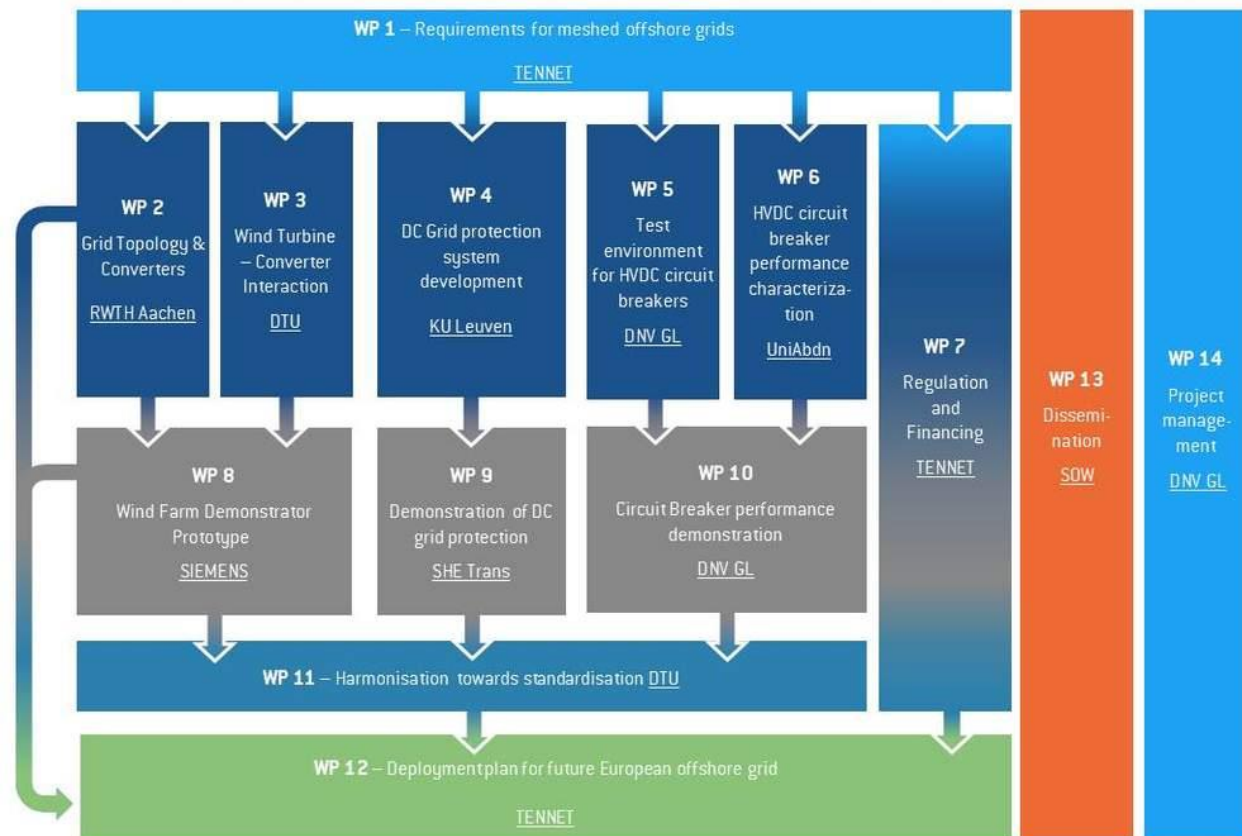
- Multiple technologies
- Multiple vendors

- HVDC grid protection

- Testing of key components

➤ Efforts to standardization
(Collaboration with Cenelec
working group WG06 „System
Aspects of HVDC Grids“)

➤ Development of a deployment
plan



Thank you for your
attention