A Pathway to Realising HVDC Grids

SSE open HVDC Forum / 22nd of May 2022 / Glasgow (UK)

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Our purpose

We energize society

Company program

Energy of tomorrow 2030

Accelerating impact to lead the energy transformation

Our people

Making the difference with our culture and values

Our technologies

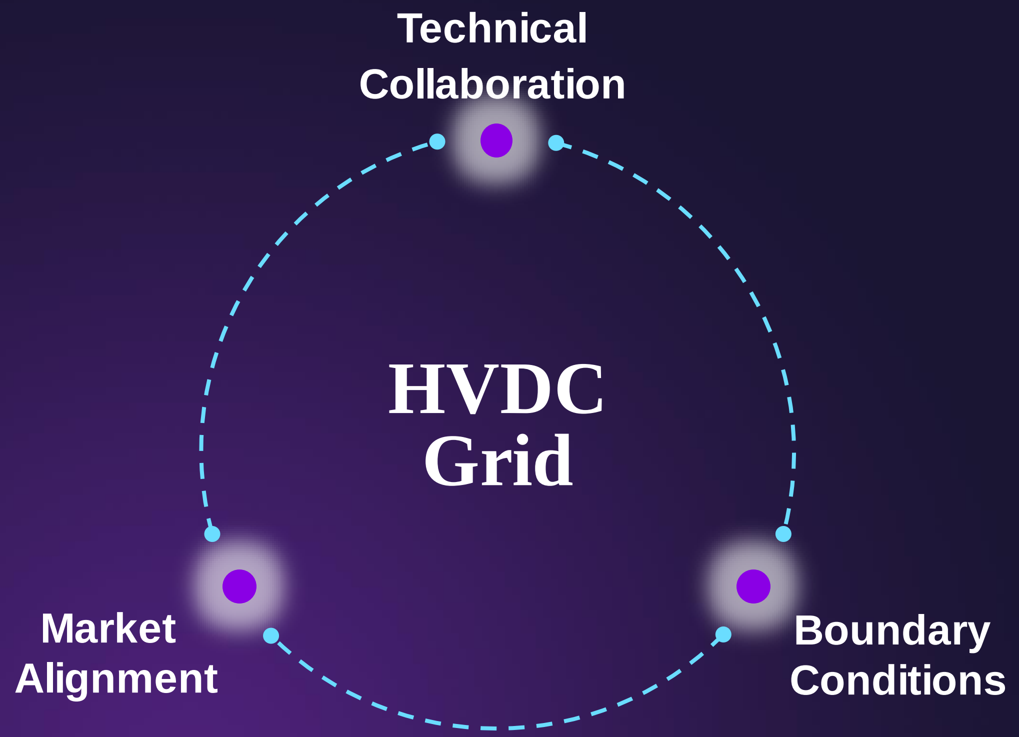
Addressing energy megatrends with our comprehensive offerings

Our customers

Co-creating solutions, innovations and delivering what we promise

The world needs sustainable, affordable and reliable energy – and NetZero is one essential element.

Coordinated action for TRANSMISSION is essential – by Vendors and by Operators.



“Europe needs a strong, meshed grid.” - ENTSO-E’s TYNDP

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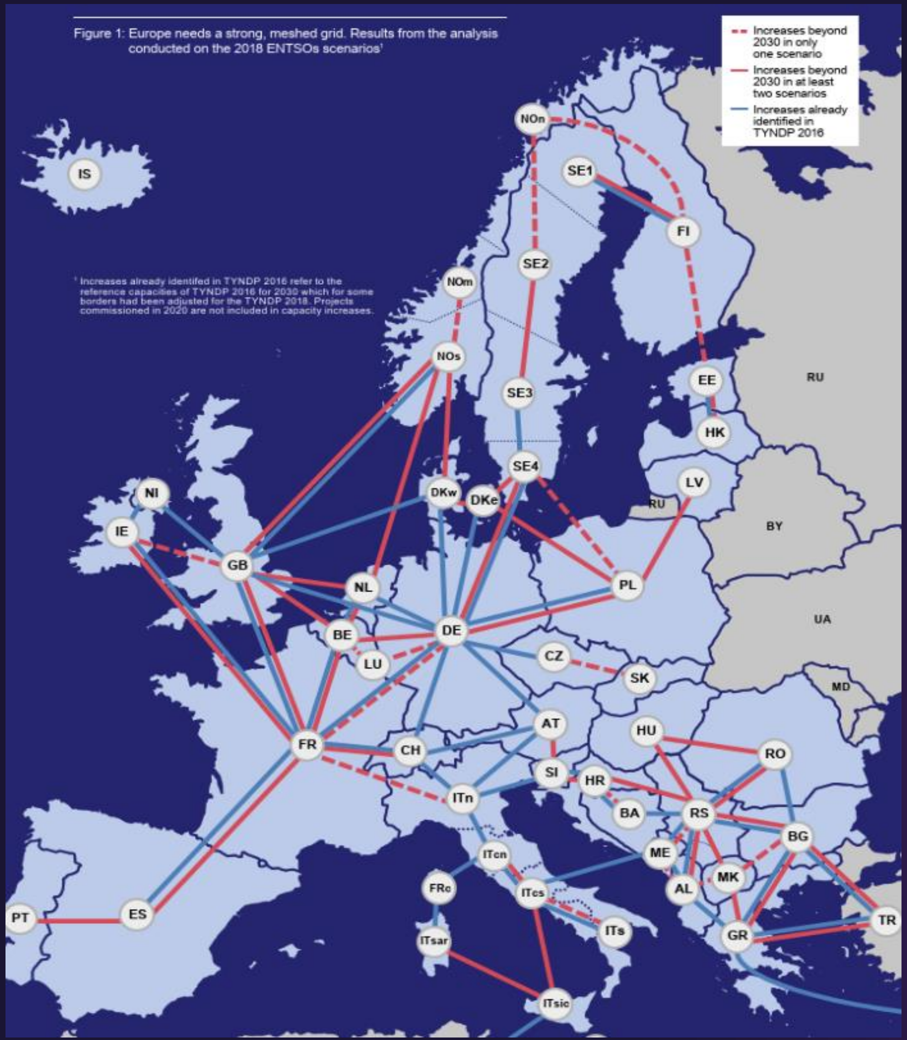
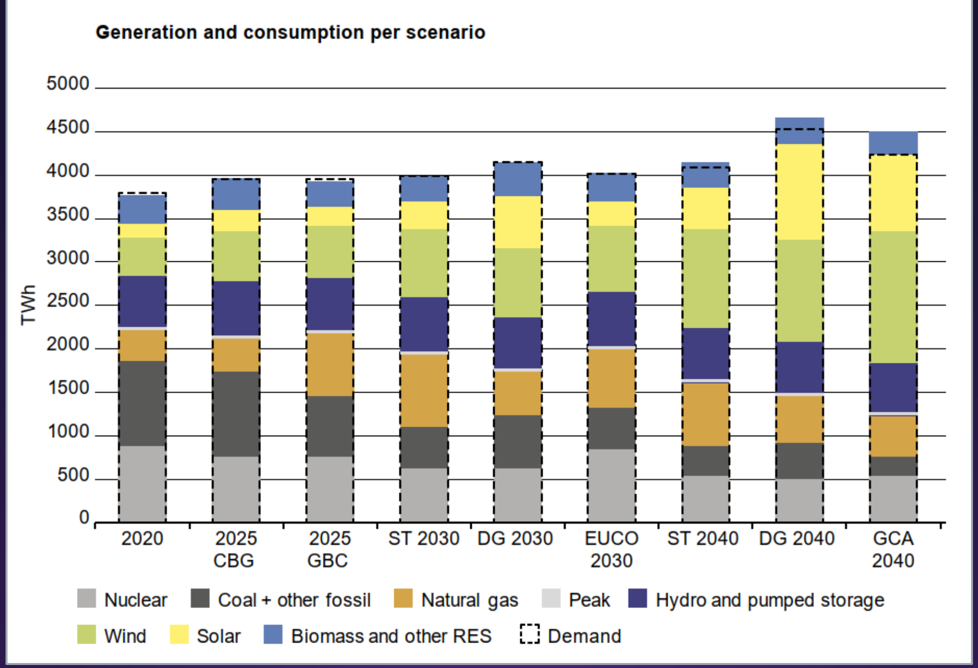


Figure 19: Electricity net generation by source and consumption per scenario



Source headline, map, diagram: ENTSO-E, European Power System 2040 Completing the map

.... “the most important question is which (on- and offshore) infrastructure is required to integrate this potential of wind energy efficiently in the energy system.”

Source citation: ENTSO-E, Regional Investment Plan Northern Seas, August 2020 Draft version prior to public consultation

Paradigm Shift
From Point-to-Point to Grid

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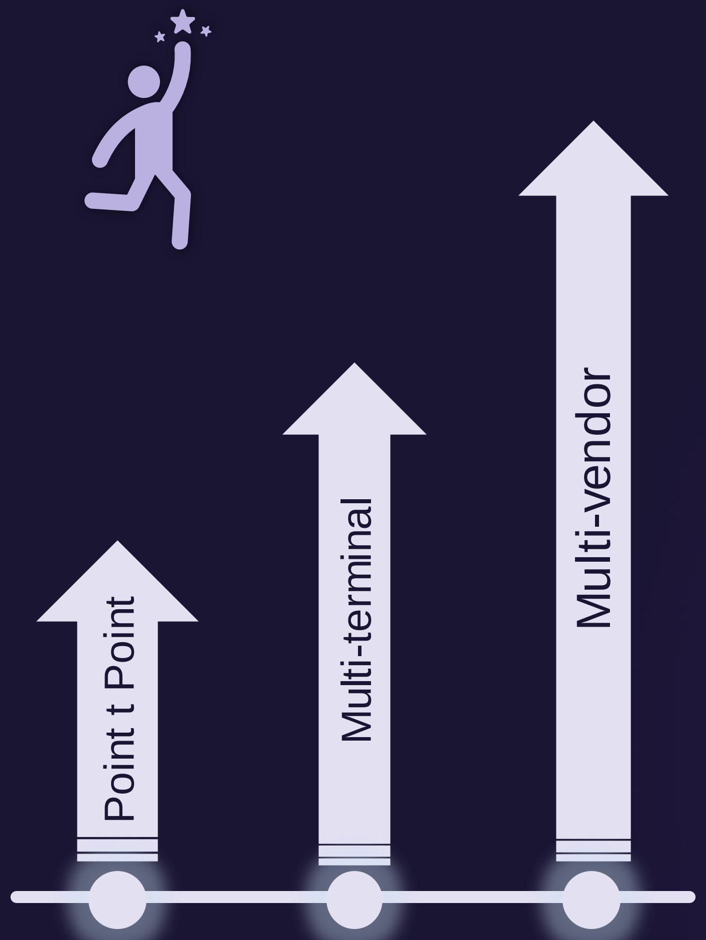


Key Design Drivers

- Resource constraint
- Time constraint
- Staged investment

- DC side fault selective seggregation
- Post contingency operation
- Resource optimisation

- AC grid interaction
- DC connection
- Ambient conditions (above and below ground)
- Performance (RAM, losses, audible noise etc.)

Solution Characteristics

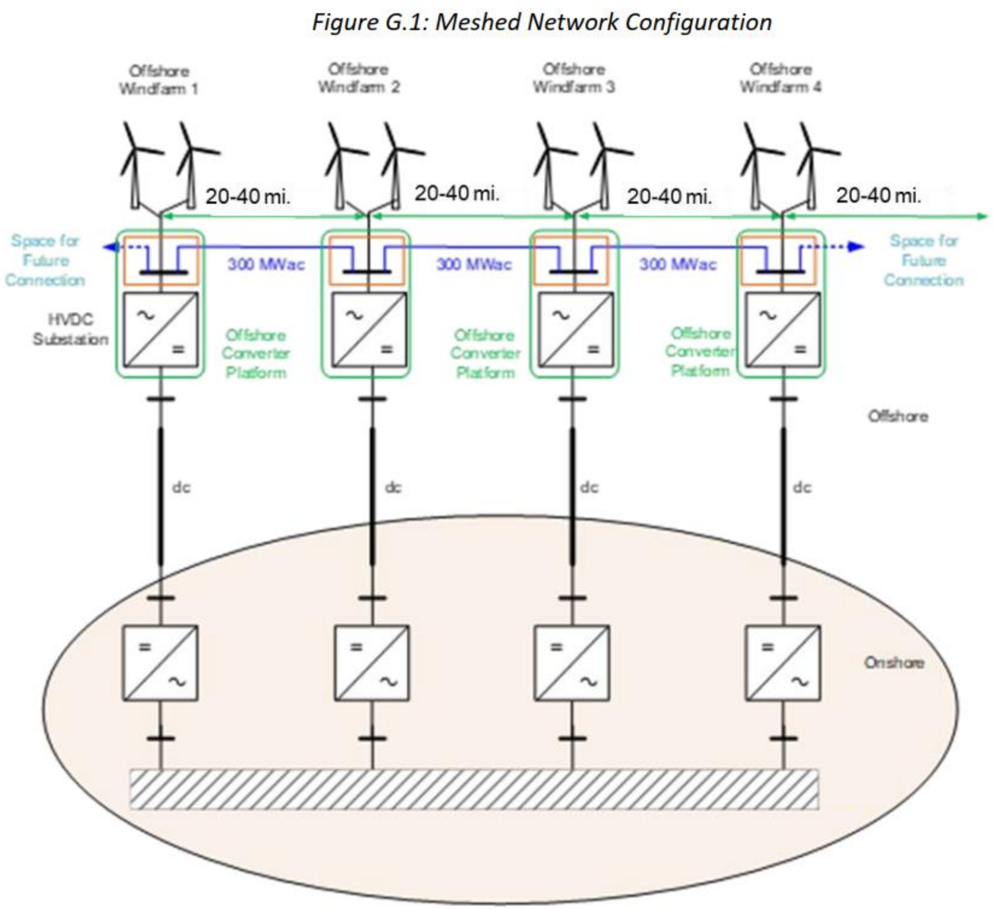
- **Co-ordinated design and selective fault separation.**
- **Standardised interfaces**
- Necessitates system integrator

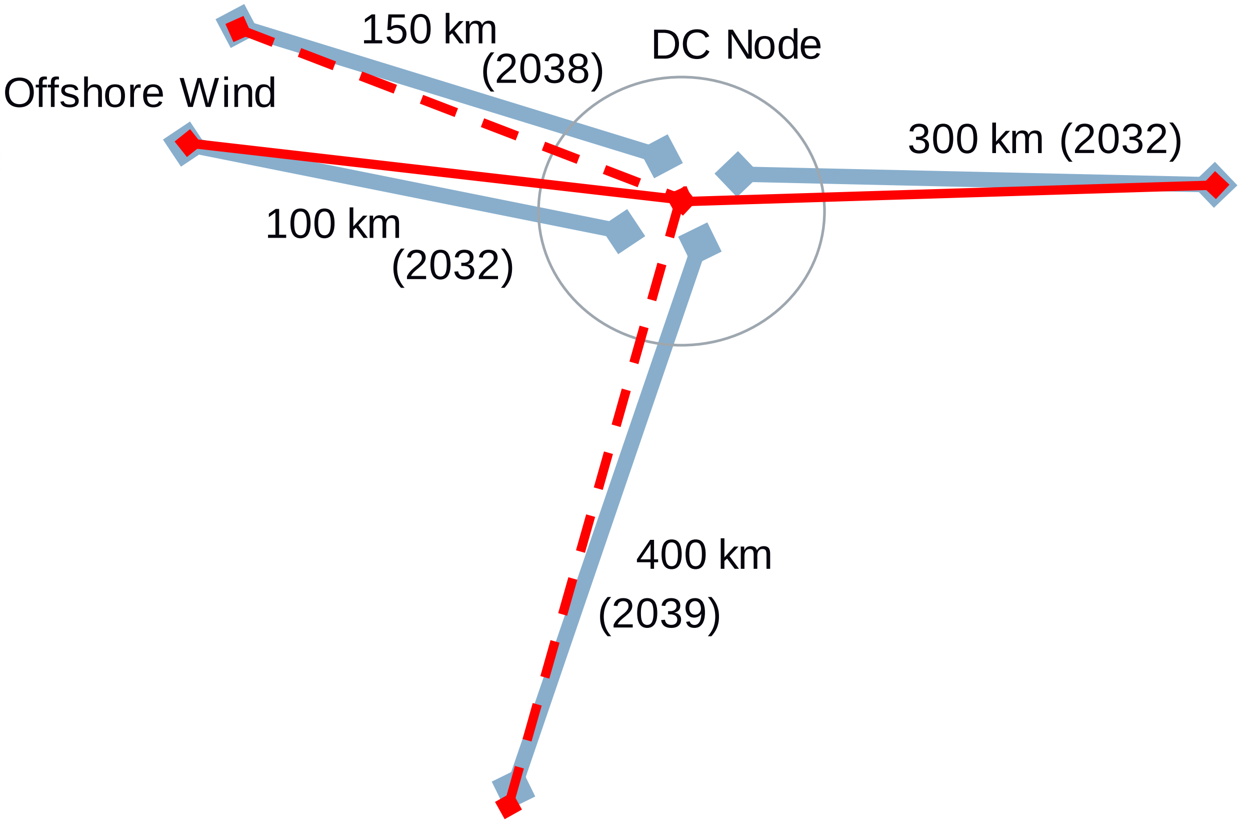
- Design margin essential for operation
- **System architecture, including selective fault separation**

- Optimised performance
- Constrained Rating (Steady state, temporary and Transient)
- **Bespoke**

Co-ordinated fault separation & standardisation of interfaces mandates Multi-Vendor Multi-TSO collaboration

AC and/or DC Side Interconnection





AC meshed and mesh-ready solutions

Key driver for Multi-Terminal Multi-Vendor HVDC solution – **Competitive market demand**

Asset optimisation

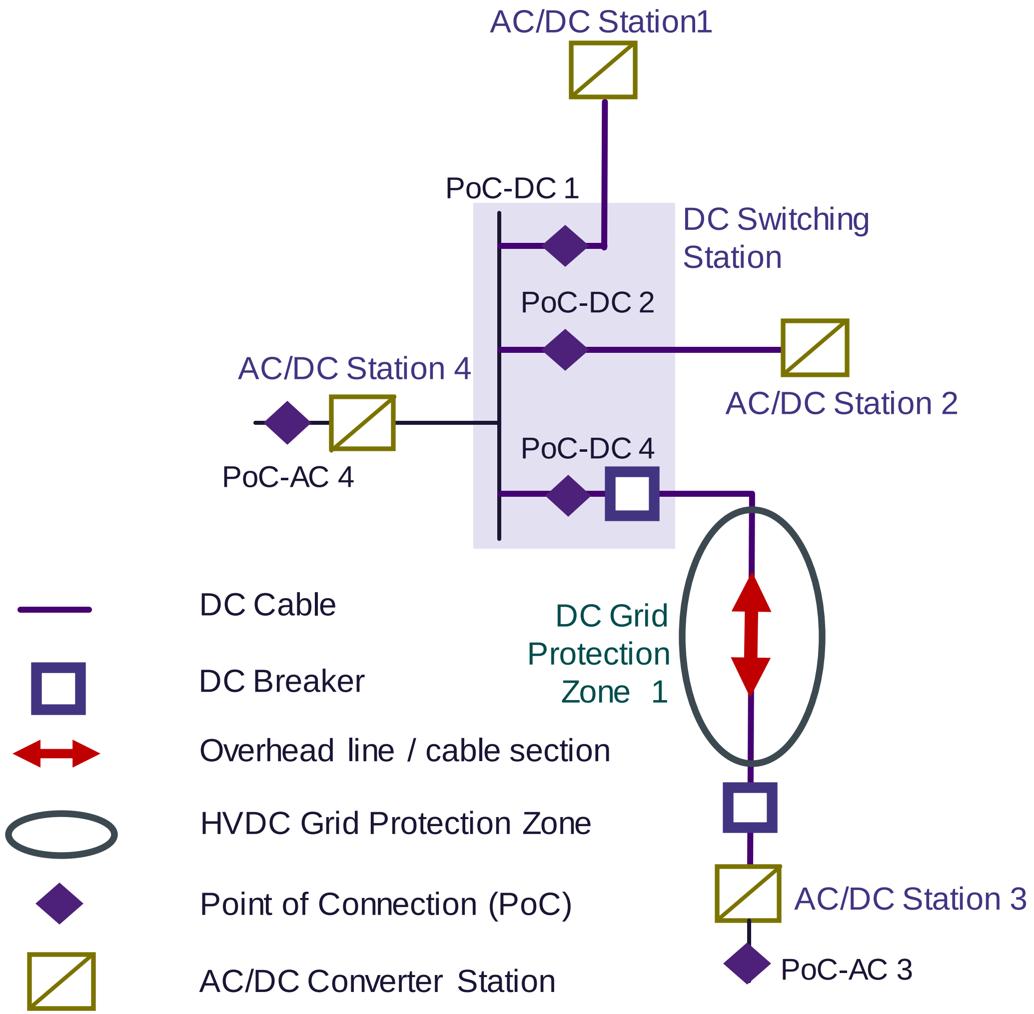
MT MV Converter Configuration

	Symmetrical Monopole	Rigid Bipole	Bipole + Return Path
Black-start			
Grid-forming			
Redundancy (50%)			
Unbalanced operation	N/A		
Power transfer continuity during reconfiguration	N/A		

Optimal system architecture dependent on AC grid and DC conductor constraints

DC Grid design philosophy - Example

Balance between selective fault isolation and system response



Ideal protection zone matrix

Faults in	PoC-AC3	PoC-AC 4	PoC-DC 4	PoC-DC 2	PoC-DC 1
Zone 1	TS-P	CO	TS	CO	CO

CO Continuous Operation

TS Temporary Stop (e.g. auto-reclosing in case of OHL faults)

TS-P Temporary Stop P, Continuous Operation Q

DC Grid	AC Grid
Converter protection tens of µs	Network contingency requirements
DC reactors for selective protection	Voltage and/or frequency support (ramp rate)

Co-ordinated requirements for DC grid based on realistic AC grid requirements

A 4-step Approach to MT MV HVDC Grids

Development Roadmap – Indicative Timeline

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1 **Today**
- MT in linear topology with Mulit Vendor readiness

2 **2023-2026**
- Multi Vendor development acc. Interoperability Workstream (Functional Specification, C&P system testing)

3 **2027/28**
- Standardisation of functional reqquirements e.g. system behaviour, interfaces etc

4
- DC Grid Codes, Parametric Standardization of
  - Converter stations
  - Switching stations
  - Grid control

Collaborative early alignment on generic MT MV architecture between TSOs and Vendors

The Journey to HVDC Grids is just Starting

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HVDC "Grids" will continue to enable the transition to a carbon-neutral energy supply

AC interconnected multi-vendor offshore HVDC can be realized today

Re-think HVDC and AC grid requirements to realize DC grids

By nature DC Grids will be multi-vendor, best developed on real requirements and proven practical applications

Practical experiences will lead to standards and standardized interfaces

Development and implementation risks manageable through a coordinated roadmap