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HVDC Innovation in Context

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HVDC Schemes in UK

HVDC schemes in commercial operation

Scheme	Owner	Country	Power (MW)	DC voltage (kV)	In service date
IFA 1[1]	NG/RTE	France	2 x 1000	±270	1985/86[2]
Moyle[1]	Mutual Energy	Northern Ireland – Scotland	2 x 250	±250	2002
BritNed[1]	NG/TenneT	Netherlands	1000	±450	2011
EWIC	EIDAC	Ireland	500	±200	2013
Caithness – Moray	SSE	Scotland	800/1200	±320	2018
Western Link[1]	NG/SPT	Scotland – Wales	2200	±600	2019
NEMO	NG/Elia	Belgium	1000	±320	2019

[1] Line Commutated Conveter (LCC) technology

[2] Valves, controls and cooling up-graded in 2012/13

HVDC schemes in construction

Scheme	Owner	Country	Power (MW)	DC voltage (kV)	In service date
Eleclink	Eleclink	France	1000	±320	2019
NSL	NG/Statnett	Norway	1400	±525	2021
IFA 2	NG/RTE	France	1000	±320	2020

HVDC schemes in planning

Scheme	Owner	Country	Power (MW)	DC voltage (kV)	In service date
Viking	NG/Energinet	Denmark	1400	±525	2024
Shetland[1]	SSE	Scotland	600	±320	2024
Greenlink	Element Power	Ireland	500	±320	2023
Aquind	Aquind	France	2 x 1000	±320	2024
Neuconnect	Neuconnect	Germany	1400	±525	2024
Gridlink	Gridlink	France	1400	±525	2024
Fablink	Transmission Investments	France	1200	±320	

[1] Forms a multi-terminal with Caithness - Moray

HVDC schemes in planning

Scheme	Owner	Country	Power (MW)	DC voltage (kV)	In service date
Western Isles	SSE	Scotland	450	±320	2023
North Connect	North Connect	Norway	1400	±525	2023
Eurolink	NG/TenneT	Netherlands	1400	±320	2030
Nautalis	NG/Elia	Belgium	1400	±320	2028
Marex[1]	Marex	Ireland	750	±320	2025
Eastern link E2DC	SPT/NG	Scotland – England	2000	±500	2027
Eastern link E4DC	SSE/NG	Scotland – England	2000	±500	2028

[1] Multi-terminal system

HVDC schemes in planning

Scheme	Owner	Country	Power (MW)	DC voltage (kV)	In service date
Tarchon	Volta partners	Germany	1400	±525	2026
Cronos	Volta partners	Belgium	1400	±525	2026
Aminth	Volta partners	Denmark	1400	±525	2026
Atlantic super connection	Atlantic super connection	Iceland	1000		2024

OFTO schemes in planning

Scheme	Owner	Country	Power (MW)	DC voltage (kV)	In service date
Norfolk Vanguard	Vattenfall		1800		
Norfolk Boreas	Vattenfall		1800		
Sofia	Innogy		1400		

Summary

HVDC Schemes	Number	Power (MW)
Operational	7	8000
Construction	3	3400
Planning	18	22500
Total	28	33900

OFTO Schemes	Number	Power (MW)
Operational	0	
Construction	0	
Planning	3	5000
Total	3	5000

Issues Related to Multiple HVDC schemes in UK

- Multi-infeed conditions, with converters at the same or adjacent PCCs
- Multi-terminal systems, converters supplied by different vendors
- Converters from multiple suppliers with different control characteristics
  - Power, reactive power, voltage, frequency
  - Emergency power control
  - Black start
- Compliance with GB Grid Code and European Grid Code

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Issues Related to Multiple HVDC schemes in UK

- Concern about mixed HVDC technologies at the same PCC
  - EWIC (VSC) - Western link (LCC)
  - IFA 1 (LCC) – Eleclink (VSC)
  - BritNed (LCC) – Eurolink (VSC)
- No issues reported from EWIC or Western Link – so far

Issues Related to changing generation in the UK

- Decreasing levels of synchronous generation on the network
  - Lower inertia
  - Lower Short Circuit Levels
- VSC HVDC may not perform well at SCR <2.0
  - Impact of network perturbations, faults, routine switching, etc.
  - Need to reduce power level
- Availability of digital models of generators for interaction studies
  - Synchronous generators
  - Non-synchronous generators

Impacts of Adjacent Converters on the Network

- Possible adverse control interactions from converters
  - STATCOMS
  - Wind Farms
  - Battery storage
  - PV arrays
- Built by multiple vendors with no coordination
- Need for interaction studies to anticipate issues which may arise

What is needed – Studies

- Interaction studies – transient and dynamic
  - Adjacent HVDC converters
  - HVDC and Other converters
- Digital studies
  - Availability of good “black box” models
  - Risk of loss of IP by vendors
- Hardware in the Loop testing, using RTS
  - Replicas
  - Secures IP of vendors

What is needed – Innovation

- Development of new HVDC converter topologies
  - Lower cost
  - Lower losses
  - Smaller footprint – OFTO applications
  - Fault blocking capability
- Development of new equipment
  - Higher current semi-conductors
  - DC circuit breakers (multi-terminal)
  - DC/DC converters (supergirds)
  - Power flow controllers (meshed systems)
  - DC GIS/GIL non-SF_6 insulant (off-shore)

What is needed – Innovation

- Increased functionality
  - Operation into low SCR
  - Synthetic inertia
  - Fast frequency response
  - Damping of system resonance conditions
- Improved protection systems
  - Converter protection
  - Network protection
    - Transducers
    - Communication
- Use of AI capabilities
- Cyber security for major national assets

Thank you for your Attention
Any Questions?