Electricity
Transmission

VoltXpanse: Ultra High Voltage (UHV) Onshore Energy Highway

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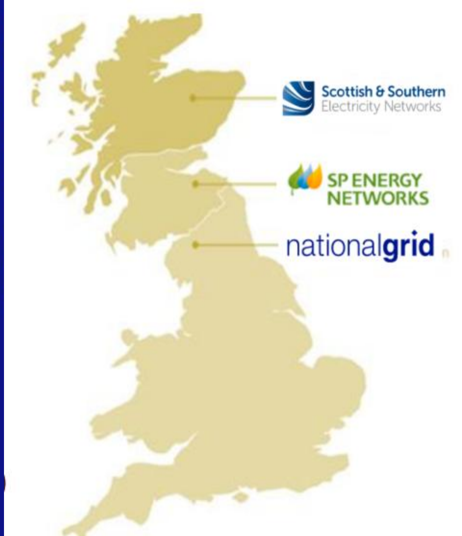
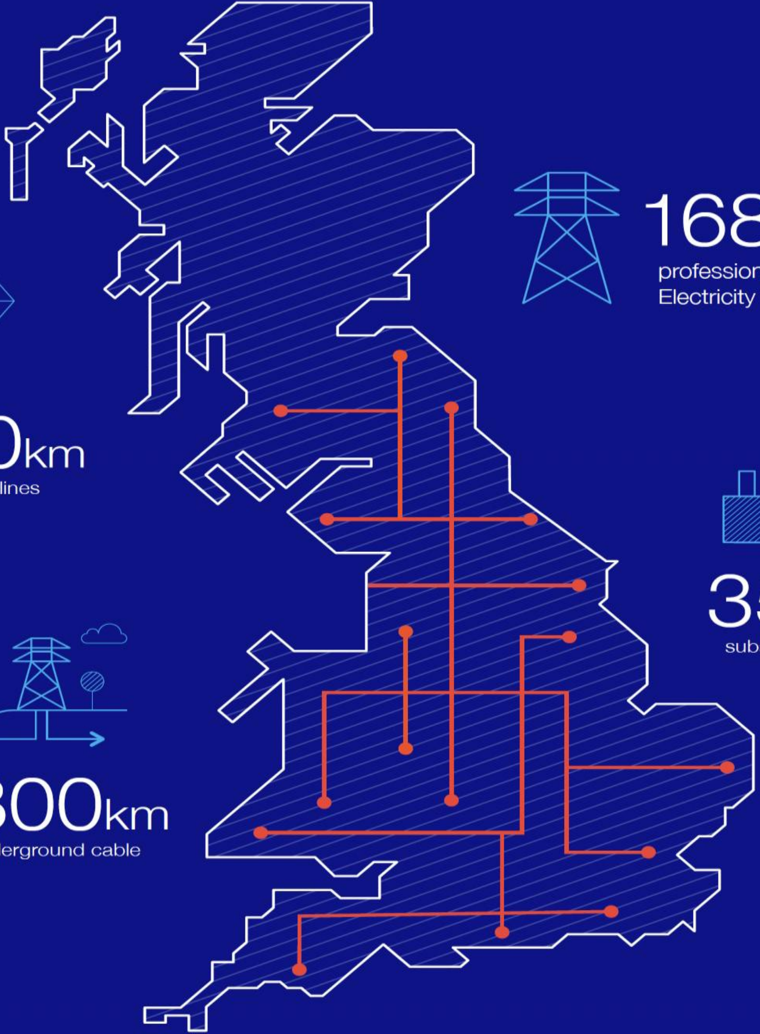
Net Zero Innovation, NGET

nationalgrid

Who we are and what we do

National Grid Electricity Transmission (NGET) owns and maintains the high-voltage electricity transmission network in England and Wales. Every time a phone is plugged in, or a switch is turned on, we've played a part, connecting you to the electricity you need.





1680
professionals working for Electricity Transmission

7000km
of overhead lines

350
substations

2800km
of underground cable

Our Purpose and Vision

Our purpose

We bring energy to life

Our vision

To be at the heart of a clean, fair and affordable energy future

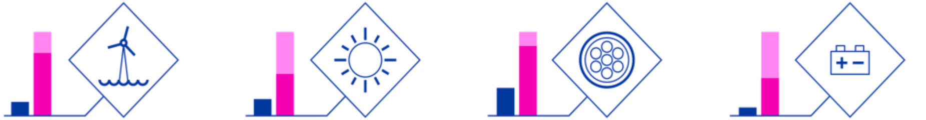
Our strategic priorities

In National Grid, we have five strategic priorities to deliver our vision:

- Enable the **energy transition** for all
- Build the **networks of the future** now
- Deliver for our **customers**
- Operate **safely and efficiently**
- Build **tomorrow's workforce** today

Background

Energy transition to Net Zero



Offshore wind	Solar	Interconnectors	Battery storage
4.5 to 6 times growth in capacity	**2.5 to 5 times** growth in capacity	**2.5 to 3 times** growth in capacity	**4.5 to 10 times** growth in capacity

At the same time cross sector electrification is expected to increase total electricity demand by around 50%.[5]

Demand growth

🚗 Transport

🔥 Heating

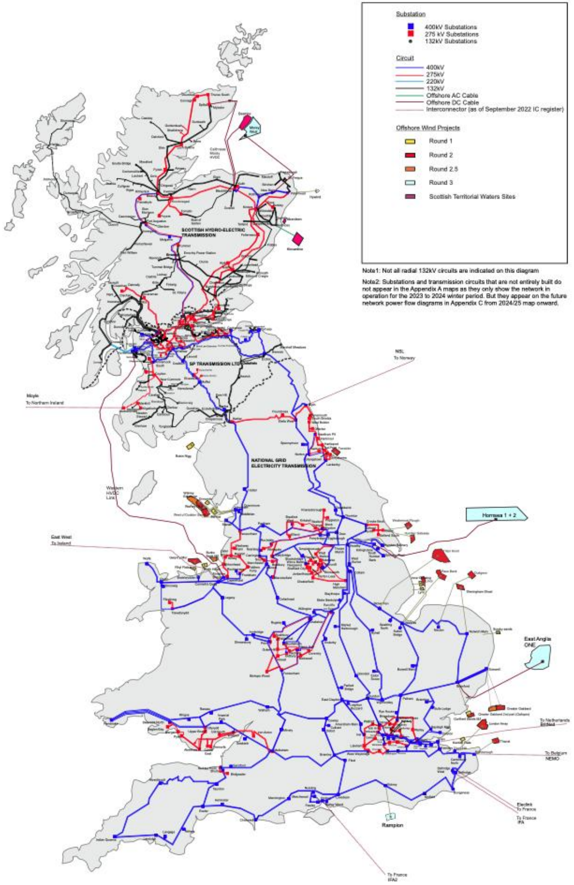
🖥 Data Centres

Hydrogen

→ **~3 times** ←

~10 times

Growing geographical misalignment between Generation & Demand

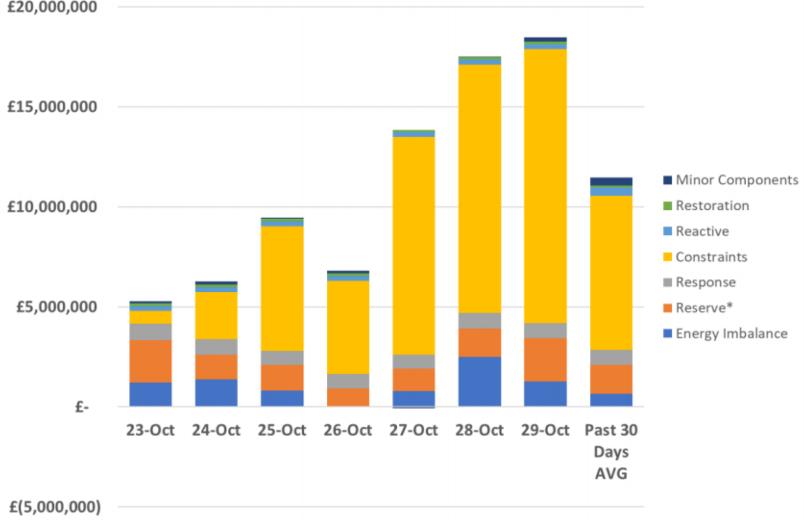


Note1: Not all radial 132kV circuits are indicated on this diagram

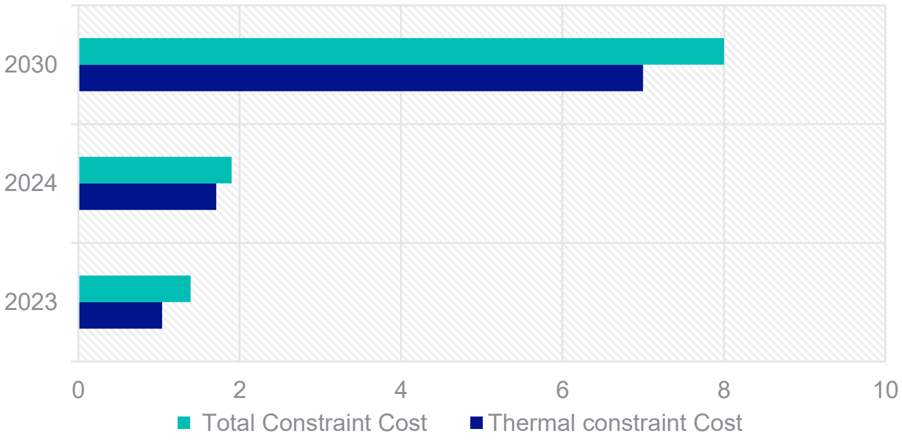
Note2: Substations and transmission circuits that are not entirely built do not appear in the Appendix A maps as they only show the network in operation for the 2023 to 2024 winter period. But they appear on the future network power flow diagrams in Appendix C from 2024/25 map onward.

Increasing Constraint Cost

Example of a weekly operation cost in 2023



Thermal constraint cost vs total constraint cost (£bn)



Need to upgrade our transmission network to increase bulk power transfer capability of the GB network.

Ultra High Voltage (UHV) OHL transmission technologies

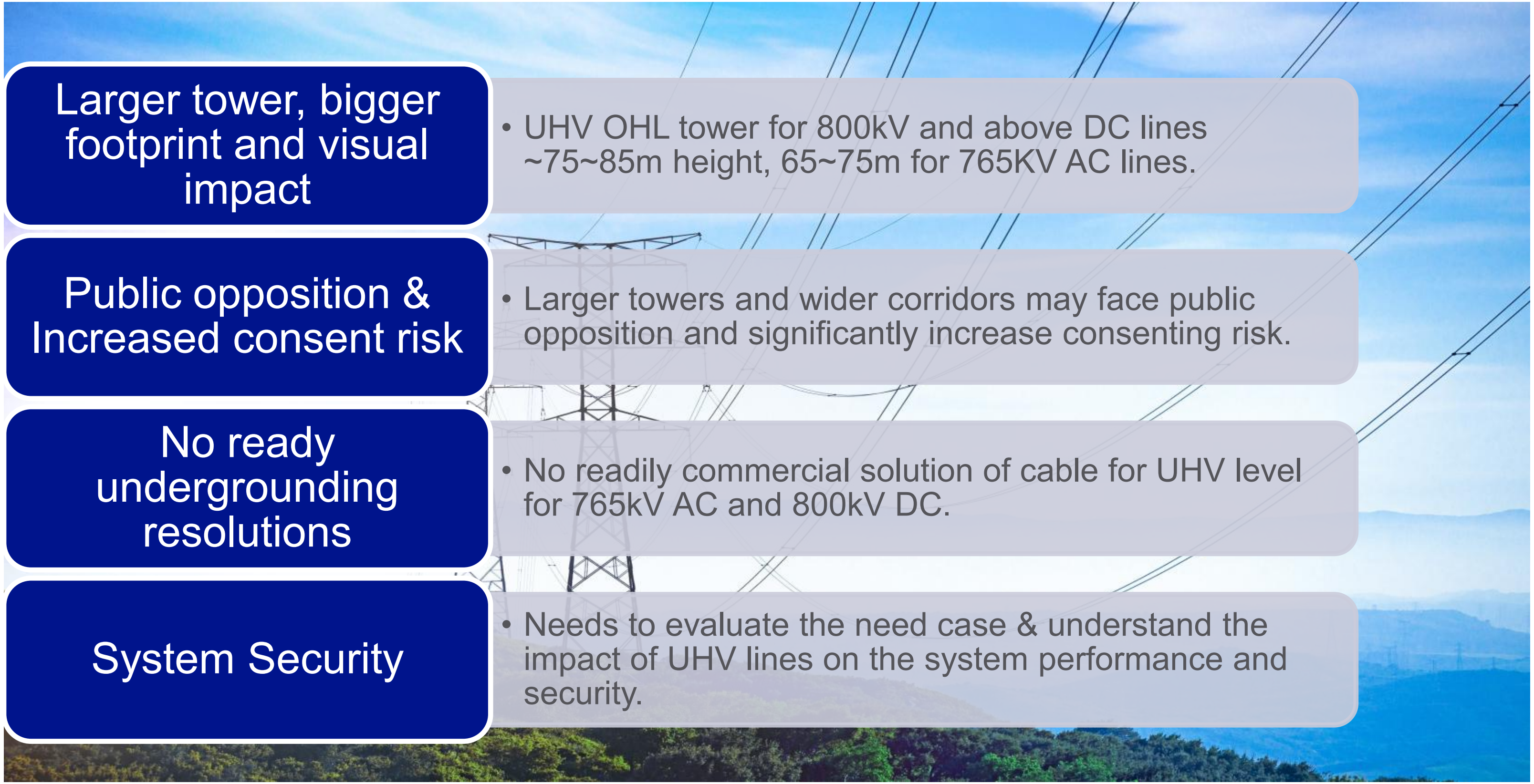
Higher Power Transfer Capacity

Reduced Transmission Losses & Enhanced Energy Efficiency

Fewer Corridors Needed

Future-Proofing the Grid

Key Challenges to deploy UHV transmission technologies



Larger tower, bigger footprint and visual impact	• UHV OHL tower for 800kV and above DC lines ~75~85m height, 65~75m for 765KV AC lines.
Public opposition & Increased consent risk	• Larger towers and wider corridors may face public opposition and significantly increase consenting risk.
No ready undergrounding resolutions	• No readily commercial solution of cable for UHV level for 765kV AC and 800kV DC.
System Security	• Needs to evaluate the need case & understand the impact of UHV lines on the system performance and security.

VoltXpanse NIA Project

We collaborate with SPEN and SSEN to investigate the feasibility of deploying UHV technologies in the GB network via VoltXpanse project.

- Identifying strategic UHV solutions for GB network onshore reinforcement
- Understanding the impacts of UHV circuits on system stability, protection and control.
- Assessing the feasibility of an innovative compact tower design for UHV overhead line (OHL) circuits
- Investigating technological and routing solutions required to ensure the deliverability of UHV circuits
- Recommending an optimal strategy to deliver the UHV circuits in an economic, efficient, and environmentally friendly way

Scope of work

Work Package 1

Strategic UHV Solutions

- Identifying strategic locations and capacities of UHV circuits
- Assessing UHV circuits' impact on system stability
- Evaluating the system's protection solution & performance

University of Strathclyde

Work Package 2

Compact Tower Design

- Reviewing overhead line and tower design criteria adopted worldwide
- Recommending compact tower design options
- Assessing audible noise and electromagnetic field implications of different overhead line and tower systems

MANCHESTER 1824

The University of Manchester

Work Package 3

Technological Feasibility

- Investigating the cutting-edge alternative to overhead lines, e.g. UHV cables, gas-insulated lines, etc.
- Investigating HVDC technology and fractional frequency transmission systems
- Assessing routing and consenting implications

Work Package 4

Optimal Delivery Strategy

- Evaluating each of the identified UHV solutions with regards to their technical deliverability, life cycle costs, reliability, network operability, carbon footprints, etc.
- Developing an optimal strategy for UHV delivery

ARUP

UHV Undergrounding Solutions-Cable

Cable :

- Strong incentives in increasing DC cable voltage, but not for AC cable.
- Charging current of AC cables increases with voltage and length, reducing effectiveness of transmission capacity.
- DC cables up to 640kV are achieved.
- CIGRE recommendations up to 800kV available for DC cable.
- More choices for DC cable solutions (XLPE, XLPEn, HTPE, etc.) than AC cables (XLPE)
- Installation engineering feasibility also needs to be carried out.

UHV Undergrounding Solutions-Gas-Insulated Lines (GIL)

- High safety and reliability, long service life
- Low power transmission loss, large transmission capacity.
- Low electromagnetic pollution & maintenance
- Maximum current rating up to 6300A
- 800kV, 1100kV technically feasible and tested for UHV AC lines (e.g HITACHI), whilst R&D is undergoing for UHV DC lines.
- SF6: One of the most potent greenhouse gases-requires alternative solutions.

diagram source: Hitachi

Huainan–Nanjing–Shanghai UHVAC transmission link-GIL in Sutong tunnel, world 1st GIL at 1000kV

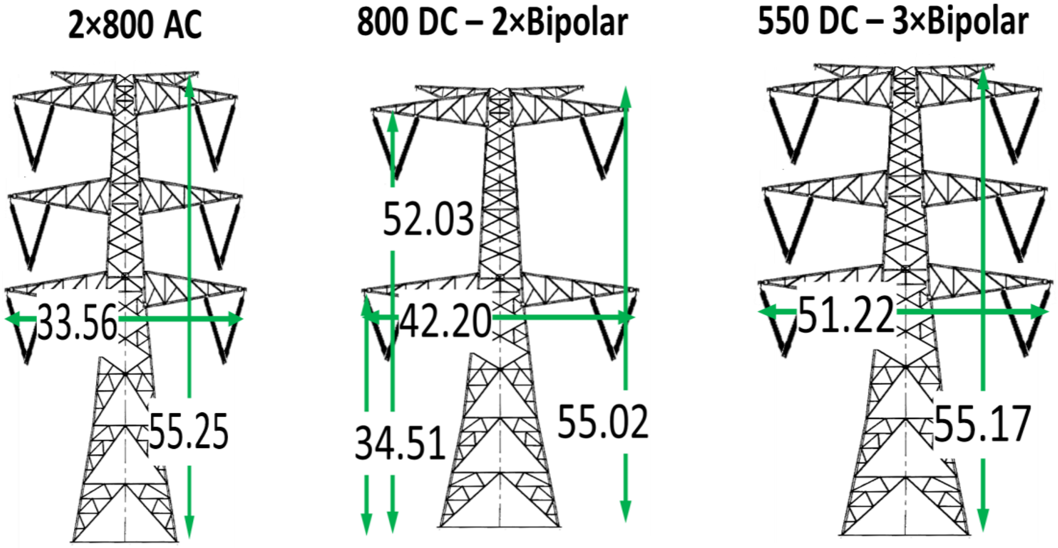
Alternative Gas-insulated lines

1st 400kV g3 installation in Sellindge, UK In service >5 years.

- Maximum capacity: 2850 MVA (at 500 kV)
- Maximum current rating: up to 4500A
- Typical voltages: 245 kV-500 kV
- Longest distance: 3.3 km @275 kV

Feasibility of Compact Tower Design

Preliminary Investigation of compact tower with a similar envelope of existing 400kV circuits



Use of V-type insulators: enabling compact top-tower geometry, reducing vertical spacing and improving swing control.

Twin shield wire system: Maintains shielding angles while supporting compact design.

Shifted top-tower geometry: Raising conductor and earth wire positions to reduce audible noise (AN) and electric field (EMF) at ground level.

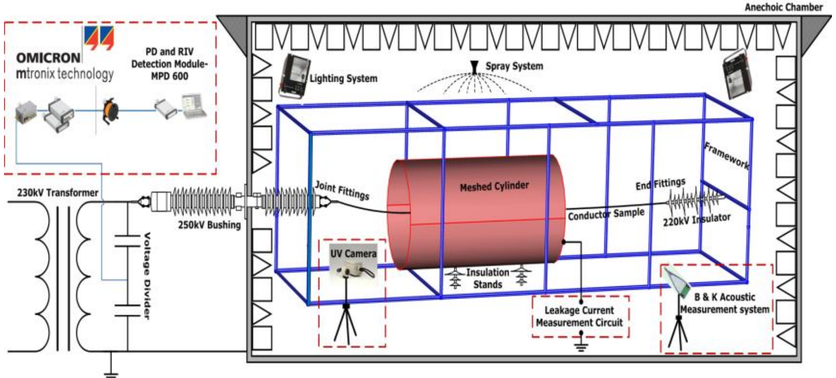
Audible Noise (AN) and Electric Field (EMF) Performance

AN reduction: raise conductor height, use larger conductors increase sub-conductors, and widen bundle spacing.

EMF reduction: raise conductor height, increase conductor size, but reduce bundle spacing and sub-conductors.

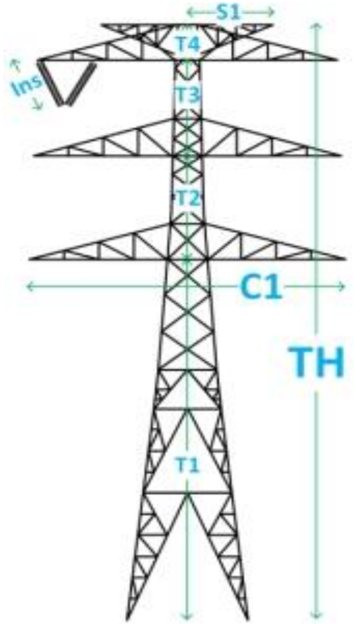
Trade-off: AN and EMF optimizations often conflict, requiring careful bundle configuration choices.

AN is lower in wet condition but higher in dry condition for DC lines than in AC lines.



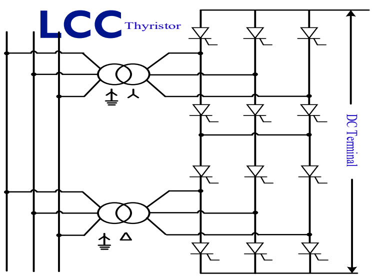
Feasibility of Compact Tower Design- 550KV

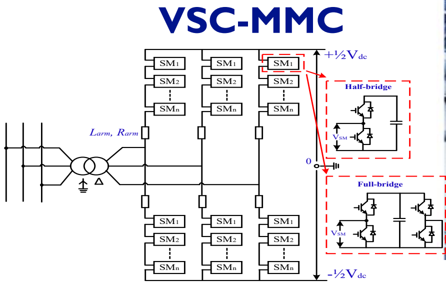
The design fits the envelope of of tower heights around 56.5m and widths of 42m.

Tower design name	Bundle Configuration	Tower Design
VW - 1.5 - LK550AC	Joree-quad--400/450/500 spacing	
VW - 1.5-LA550DC*	Araucaria-triple/quad-400/450/500 spacing Redwood-twin/triple/quad-400/450/500 spacing Joree-twin/triple/quad-400/450/500 spacing	
VW - 1.2 - LK550DC	Araucaria-twin-450/500 spacing Araucaria-triple/quad-400/450/500 spacing Redwood-twin/triple-400/450/500 spacing Joree-twin/triple/quad-400/450/500 spacing	
VW - 1.2 - LA550DC*	Araucaria-triple/quad-400/450/500 spacing Redwood-twin/triple/quad-400/450/500 spacing Joree-twin/triple/quad-400/450/500 spacing	
VW - 1.5 - LK550DC	Araucaria-triple/quad-400/450/500 spacing Redwood-twin/triple-400/450/500 spacing Redwood-quad-400/450 spacing Joree-twin/triple-400/450/500 spacing Joree-quad-400/450 spacing	

* The design is based on 12.6m of sag. Current 400 kV systems consider 12.25 m sag.

HVDC Technology





HVDC VSC (diagram source: ABB)

LCC

- High power capability (up to 12 GW)
- High voltage level (up to ±1100 kV)
- Requiring strong AC grids
- Lack of flexibility in changing DC current direction

VSC-MMC

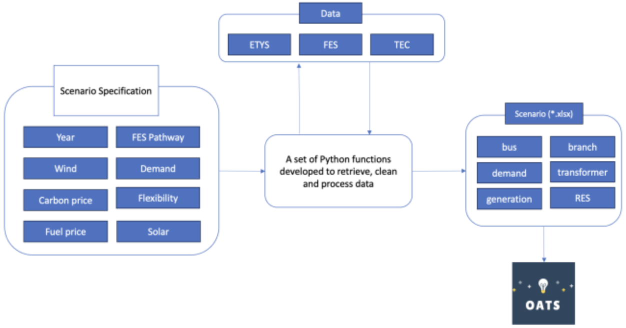
- High voltage and power capability (±800 kV, 8GW in Gansu – Zhejiang UHVDC project)
- DC fault current blocking capability like Full-bridge MMC
- Operate in weak grid
- Converter Rating is limited by the rating of IGBT
- Complex structure and control strategy

Strategic Solutions of UHV Links

1. Credible set of future operation conditions

2. Development of Representative GB transmission system

3. Assessment of UHVDC transmission needs



Data

ETYS

FES

TEC

Scenario Specification

Year

FES Pathway

Wind

Demand

Carbon price

Flexibility

Fuel price

Solar

A set of Python functions developed to retrieve, clean and process data

Scenario (*.xlsx)

bus

branch

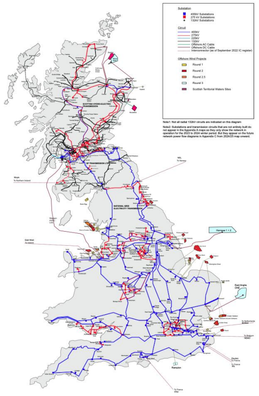
demand

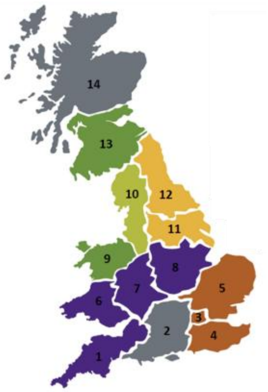
transformer

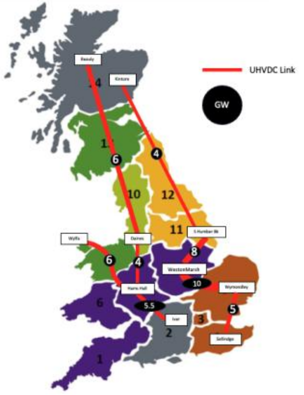
generation

RES

OATS







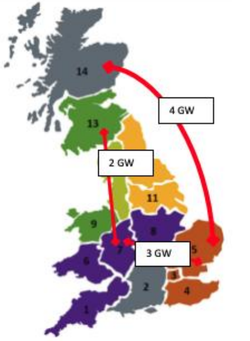
Using industry data (FES, ETYS, TEC register), we developed a systematic approach to build credible GB operational conditions up to 2050, generating 50,000+ scenarios to assess the need and value of UHV links.

Developed in this project: a high-resolution GB model for spatial insights, from individual substations to aggregated GSP groups

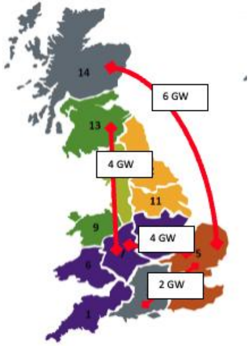
Using the project-developed scenarios, assess optimal locations and capacities for UHV links.

Key Outputs

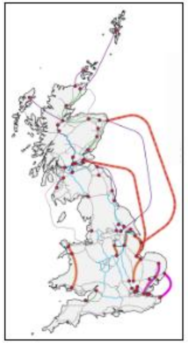
- **Additional 15 ~ 25 GW UHV transmission capacity required to integrate renewables and reduce curtailment**
- **Strong and persistent need for North – South transmission**
- **Results align with Clean Power 2030, and Beyond 2030**
- **Identify additional growing need for East – West connections**
- **Benefit illustration: A 6 GW UHV link between Scotland and the Midlands can save £0.5 billion annual dispatch cost, 2.7TWh wind curtailment**
- **Ongoing studies against more scenarios and work to assess indicative cost savings for UHV build-out**



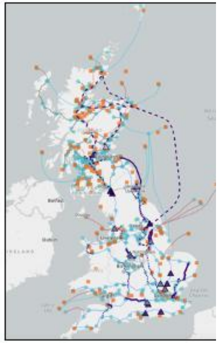
2030



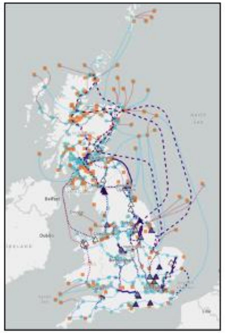
2040



Clean Power 2030

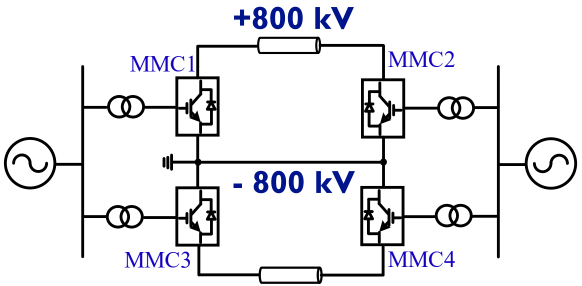


Beyond 2030



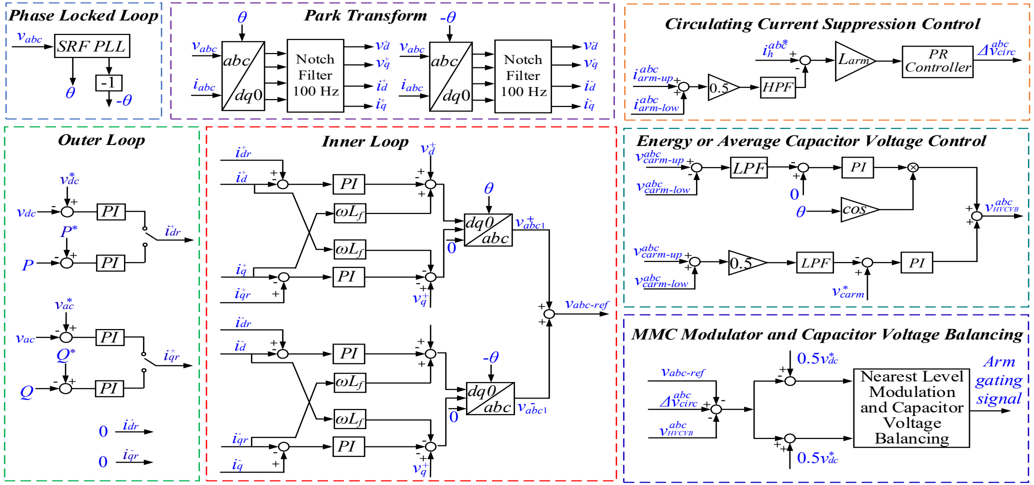
Beyond 2030

UHVDC Model Development in RTDS



- $\pm 800\ kV$, **8 GW in total**
- **MMC1 & MCC3 – Power control**
- **MMC2 & MMC4 – DC control**
- **Both full-bridge and half-bridge models have been developed**

Controller of Individual MMC station:

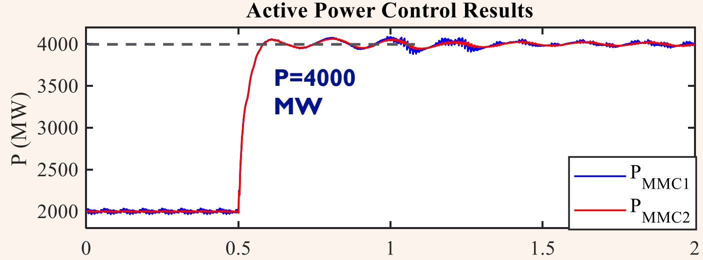


Model Validation in RTDS:

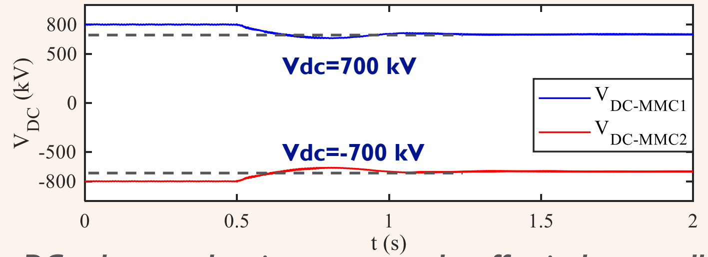
Case	Conditions
A1	Power references of MMC1 and MMC3 change from 2 GW to 4 GW at t = 0.5s
A2	DC voltage references of MMC2 and MMC4 change from $\pm 800\ KV$ to $\pm 700\ KV$ at t= 0.5s

Simulation Results:

Active Power Control Results



DC Voltage Control Results



The DC voltage and active power can be effectively controlled. UHVDC models are used in stability and protection studies.

Protection Consideration for UHVDC

- No commercially available DC circuit breaker for UHVDC links
- **Fault interruption relies on AC-side breakers or on converters with blocking capabilities, such as the full-bridge topology.**
- Unlike cable-based HVDC projects, temporary **faults are frequent in** OHL UHVDC systems, therefore, **fast fault interruption and recovery strategies** need to be considered.

Full-bridge can block fault current within a few milliseconds.

Fast fault recovery can be achieved by implementing full-bridge topology.

The AC break-based strategy could take a few seconds, much longer to recover the system [1].

[1] Int. Electrotech. Comm., "High-voltage direct current (HVDC) transmission using voltage sourced converters (VSC)," IEC Tech. Rep. TR-62543, 2022.

Look Ahead

VoltXpanse will work closely with all key stakeholders to advance investigations within each work package. The primary areas of focus include :

- Finalising strategic locations of UHV circuits in the GB network. while assessing their potential system impacts.
- Designing compact tower for 800kV DC in detail
- Conducting cost benefit analysis and developing an optimal delivery strategy for UHV solutions in the UK

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Q&A

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