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Net Zero Innovation
National Grid Electricity Transmission

By Neha Moturi
neha.moturi@energyq.com.au

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Disclaimer

This report provides a candid assessment of the author's experiences drawing comparisons to the Australian electricity supply industry. Statements and material contained within this report (except where explicitly referenced) are the expressed opinion of the author and do not relate to any person or organisation associated with the author. Any reproduction or referencing of this report should reflect this.

Abbreviations

CCC	Committee of Climate Change
ESO	Electricity System Operator
EV	Electric Vehicle
FES	Future Energy Scenario
GB	Great Britain
HND	Holistic Network Design
HVDC	High Voltage Direct Current
IDD	Infrastructure Development and Delivery
LW	Leading the Way
NG	National Grid
NGED	National Grid Electricity Distribution
NGET	National Grid Electricity Transmission
NGP	National Grid Partners
NGV	National Grid Ventures
NPg	Northern Powergrid
NZI	Net Zero Innovation
Ofgem	Office of Gas and Electricity Markets
QEJP	Queensland Jobs and Energy Plan
ST	System Transformation
V2G	Vehicle-to-Grid
VSC	Voltage Source Converter

Executive Summary

The global energy sector is undergoing a significant and exciting period of change as we transition to a net zero carbon future. UK transmission and distribution service providers have published various future energy system predictions (known as Future Energy Scenarios) to help inform current day network investment decisions, policy changes and carry out innovation accordingly. Whilst these future scenarios equally achieve net zero, they are diverse in technology uptake, consumer behaviour, regulation and government policy, renewable generation mix etc. further emphasising the level of uncertainty ahead of us.

The complex nature of the future energy system and how its various elements interact with each other requires 'Whole System' thinking, which involves collaboration with other network licensees and participants in the wider industry. I am excited to be working as an Innovation Engineer in the Net Zero Innovation Team at National Grid Electricity Transmission (NGET) as my first placement. More specifically, my primary responsibility is to look after the Whole System portfolio of projects which has given me exposure to a diverse array of technologies and services that are strategically designed to benefit our networks whilst also delivering best value to customers.

In this report, I have summarised two innovation projects, namely the Vehicle-to-Grid (V2G) project and the Ultra-High-Voltage project. The V2G project takes a novel approach to quantifying the potential peak demand reductions from smart charging and V2G services. The modelling performed considers predictions for the future behaviours around the adoption of EV technologies and smart charging capabilities. The HVDC project is driven by the need to significantly increase transmission network capacity to meet future demand. Ultra-high-voltage solutions beyond 400kV AC for both overhead and underground transmission are considered, and compact tower designs are proposed.

Finally, I have summarised my future plans within the Net Zero Innovation Team and included a summary of my learnings from one of the many industry events I have been fortunate enough to attend whilst in this placement.

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Overview of National Grid

National Grid is a multinational company operating in both the UK and US. Within the UK, the National Grid group encompasses National Grid Electricity Transmission (NGET), National Grid Electricity Distribution (NGED), the Electricity System Operator (ESO), National Grid Ventures (NGV) and National Grid Partners (NGP) as summarised below.

1. National Grid Electricity Transmission (NGET)

NGET owns the high voltage electricity transmission network in England and Wales. Figure 1 provides a snapshot of NGET [1].

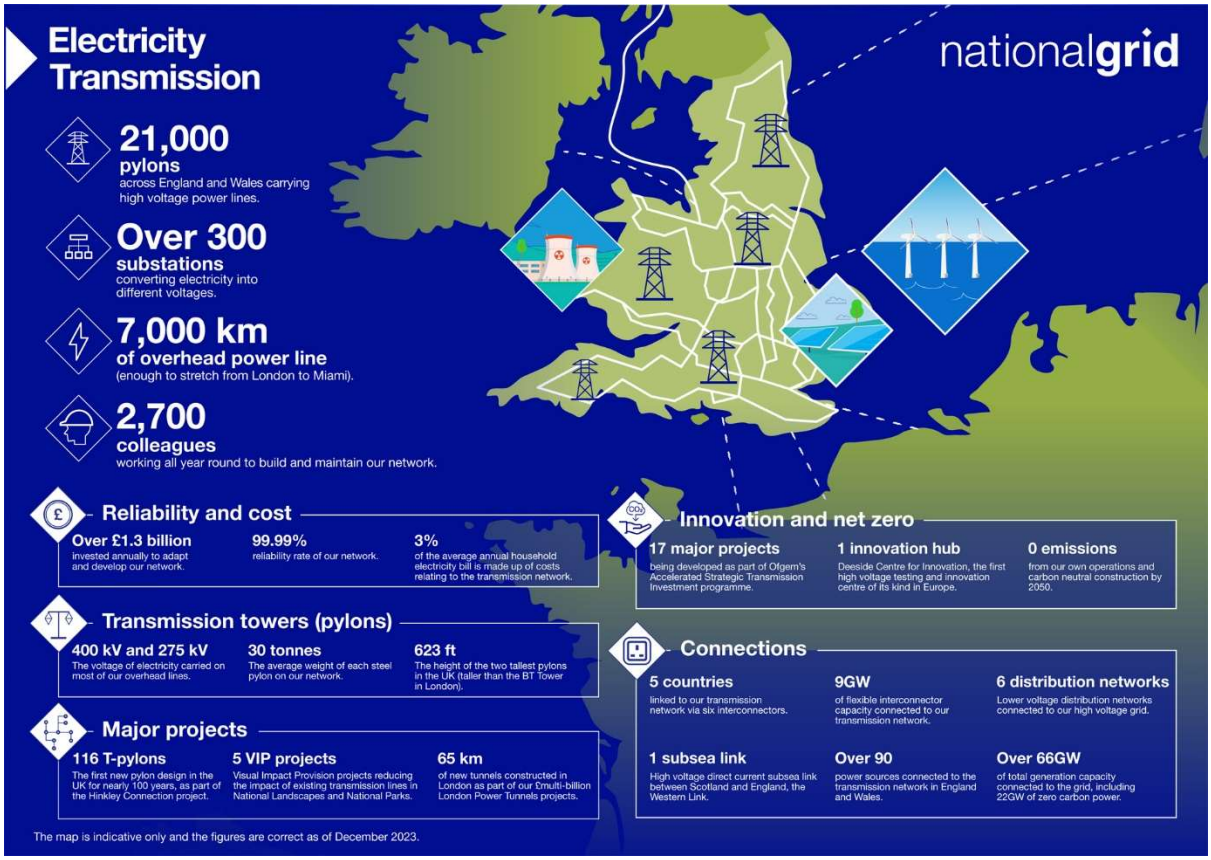

Figure 1 National Grid Electricity Transmission (NGET) Overview [1]

2. National Grid Electricity Distribution (NGED)

NGED is formerly known as Western Power Distribution and manages the UK's largest electricity distribution network (approximately 550,000 square kilometres). Comprised of 6500 employees, NGED serves approximately 8 million customers in the East and West Midlands, South West and Wales [2].

3. Electricity System Operator (ESO)

The ESO has recently become a legally separate business within the National Grid group. The new organisation will build on its current activities and capabilities by adding value in areas such as strategic planning, security of supply, resilience, market development and net zero energy insights [3].

4. National Grid Partners (NGP)

NGP is an investor-owned energy company launched in 2018 with the purpose of investing in startups and innovators as a way to disrupt the industry with new technologies and services [4].

5. National Grid Ventures (NGV)

NGV operates separately from the core regulated business and develops, operates and invests in large-scale clean energy infrastructure. NGV's portfolio of projects includes (but not limited to) electricity interconnectors, offshore hybrid assets, offshore wind, battery storage and hydrogen [5].

Ofgem

The Office of Gas and Electricity Markets (Ofgem) sets price controls for gas and electricity network companies in Great Britain. The regulatory framework is known as RIIO, which allows network companies to earn Revenue (R) through Incentives (I), Innovation (I) and Outputs (O). Currently, we are in the second set of price controls implemented under the RIIO model, referred to as RIIO-2 or T2, which runs from April 2021 to March 2026. This framework is a means for network companies to engage in innovation and secure funding for the development of a sustainable, low-cost network [6].

Prior to the commencement of a price control period, network companies are required to submit a business plan to Ofgem for review and assessment. Business plans outline how the total requested business expenditure will meet stakeholder and consumer priorities. For example, NGET's business plan for the T2 period called for £7.1bn of investment as shown in Figure 2, an 18% increase from the T1 period to deliver (and not limited to) [7]:

- An increase in network capacity of 22.5 giga-watts (GW), which will avoid system operation costs of at least £250m per year
- Connect 15.3GW of customer capacity, providing the UK with clean power, flexible storage and access to clean and cheaper power from Europe.
- World-class levels of safety and service reliability of 99.9999 per cent
- Three major electricity cable projects in London, Sheffield and North Wales to maintain security of supply.
- Innovation in the areas of SF6 insulation gas, EV uptake and sourcing 100% of metered electricity from renewables.
- Digitisation, artificial intelligence and data sharing particularly in the context of reducing asset management costs.

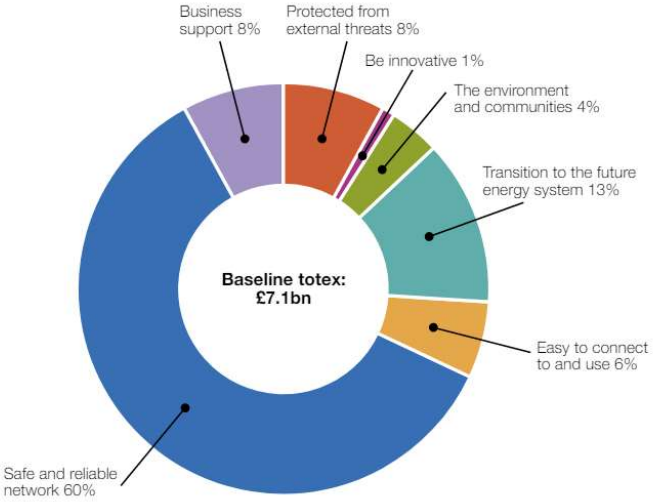

Figure 2 Drivers for NGET's T2 Business Plan

Net Zero Innovation (NZI)

What is my role?

I am based in the Strategy and Innovation group within the Infrastructure Development and Delivery (ID&D) group at National Grid Electricity Transmission. More specifically, I work as an Innovation Engineer in the Net Zero Innovation Team reporting to Gary Stockdale (Net Zero Innovation Manager).

The Net Zero Innovation Team consists of 13 people, and collectively we manage the following portfolios:

1. Substations
2. Protection, Control, and Instrumentation
3. Circuits
4. Whole System
5. Power System
6. Climate Resilience
7. Net Zero Construction

I specifically look after the Whole System portfolio of projects. The definition of Whole System and example projects from this portfolio are provided in a later section.

How are innovation projects funded?

Innovation Projects can be funded via three different mechanisms as detailed below:

1. Network Innovation Allowance (NIA)

Ofgem facilitates funding for innovation projects via the NIA as part of the RIIO-2 price controls. It is a set allowance for network companies to fund smaller technical, commercial or operational projects that benefit the licensees' network. As per the RIIO-2 NIA Governance Document, each NIA innovation project must:

- Facilitate energy system transition and/or benefit consumers in vulnerable situations
- Have the potential to deliver a net benefit to consumers
- Involve research, development or demonstration
- Develop new learning
- Be innovative
- Not lead to unnecessary duplication.

2. Strategic Innovation Funding (SIF)

For RIIO-2, Ofgem replaced its Network Innovation Competition (NIC) framework with Strategic Innovation Funding with £450m available for Great Britain networks over the five-year regulatory period. This is an additional innovation funding mechanism to the NIA which network licensees can apply to. SIF projects are large-scale, transformational projects which typically require demonstration activities and must involve collaboration with the wider industry. Funding is awarded if projects can address the Innovation Challenge set by Ofgem.

Unlike NIA funded projects, SIF adopts a three-stage approach for project funding, namely: Discovery Phase (i.e. feasibility and research stage), Alpha phase (i.e. experimental stage) and Beta phase (i.e. demonstration/building phase). There are no guarantees that an innovation project which has been successful for Discovery phase will proceed to Alpha phase and beyond, and similarly, an innovation idea can bypass the Discovery phase if the technology meets Alpha phase criteria.

Another point of difference worth noting is that NIA funding allocations are made by networks as per their internal business needs whilst Ofgem is the decision maker for SIF funding.

3. Self-Funded Projects

Innovation is self-funded through various projects; most recent examples are:

- London Power Tunnels concrete pour
- New Plug and Switch System (PASS) bay at Willesden Substation
- Shunt Reactor Bay at Stalybridge Substation
- Bengeworth Road SF6-free substation

Deeside Testing

The Deeside Centre for Innovation is a controlled test environment encompassing 19 acres of land which includes a modified substation, overhead line (OHL) test areas, workshops, storage space and offices. The centre facilitates innovative design and technology validation, long duration resilience testing and ultimately allows network operators to make strategic investment decisions. The site is comprised of:

- 400 kV electrical substation equipment
- Supplied via 11 kV RMU
- 8 dedicated fenced off test areas
    - 6 substation HV test areas
    - 2 OHL test areas
- Test areas for electrical and mechanical testing of HV asset and OHL equipment

So far the site has facilitated the successful delivery of projects such as:

- SF_6 leak sealing trial testing
- Ultra-low carbon concrete testing
- Hydrogen powered backup generator

Ongoing projects which are utilising the centre include:

- 400kV composite insulator testing
- Retro-filling SF_6 equipment with environmentally friendlier gas
- Overhead line conductor coating project
- Conductor vibration testing

Whole System Thinking

What is whole system?

Traditionally, the electricity, gas, oil, water industries and other relevant players in the wider industry have operated independently to meet their individual needs. A whole system approach requires thinking beyond our own networks and refers to the cooperation with other network licensees to deliver network solutions and services that deliver best value to the customer. It requires effective collaboration and sharing of resources between these parties to roll-out optimised future network solutions.

Whole System Strategy

The whole system themes I prioritise in my role are heavily influenced by various future energy system predictions. The Committee of Climate Change (CCC) and the National Energy Service Operator (NESO) have both published their own future energy scenarios (FES), however given the uncertainty and economic detail required for a net zero system, these scenarios are purely an educated guess of the future energy landscape and mainly serve to demonstrate the size of the challenge ahead of us. NESO's FES encompass four scenarios, namely: "Falling Short", "System Transformation", "Consumer Transformation" and "Leading the Way (LW)". All FES scenarios equally deliver Net Zero however with different approaches. A comparison of CCC's FES and NESO's LW scenario are compared below [8, 9]:

Table 1 Consumption by Sector (TWh)

	2022	CCC 2050	NESO LW 2050
Industry	256	269	329
Transport	592	240	314
Domestic	399	425	168
Services	235	334	347
TOTAL	**1482**	**1268**	**1158**

Table 2 Energy by Source (TWh)

	CCC 2050	NESO LW 2050
Electricity	722	751
Hydrogen	223	105
Natural Gas	217	64
Other Fuels	105	88
Bio resource	-	160
TOTAL	**1267**	**1168**

A few observations from the FES that are considered in existing whole of system plans are outlined below:

- Energy consumption due to transport reduces from 592 TWh in 2022 to around 240TWh in 2050 without the need for significant reduction of number of cars.
    - Hydrogen fuel cells and battery electric vehicles are replacing internal combustion engines (ICE) and have much better energy efficiency.
- Better insulation and new heating technologies including electric heat pumps will reduce domestic energy consumption to around 425TWh in 2050 from 399TWh in 2022.
- Electrolytic hydrogen production has the potential to deliver whole system benefits if located strategically and utilised as storage to create competitive markets. Considerations should include proximity to network constraints, end users and transportation and storage of hydrogen.
- Growth of embedded generation and an increase of energy flowing onto the electricity transmission network from distribution level needs to be further explored.

Innovation Projects

Each NIA innovation project follows a 5-stage philosophy, namely: Idea, Initiation, Delivery, Closure and Closed. Each stage requires a number of actions to be undertaken, completed and approved by managers before moving on to any subsequent stages. This is primarily for auditing, governance and reporting purposes both internally and externally. Contract management and negotiation is a key aspect of the role as various suppliers (i.e. manufacturers, consultants and universities) are engaged to help deliver projects.

Case Study 1: V2G Peak Demand Reduction

What is the problem?

Ofgem has suggested that smart charging of EVs and V2G together could reduce peak demand by as much as 32GW by 2050, potentially more than offsetting the additional peak demand from EVs (estimated at 19-26GW in 2050).

Realising the potential peak demand reductions from smart charging and V2G will depend on many factors. These include consumer behaviour, developments in charge-point technology and developments in battery technology. National Grid is working with Frontier Economics, Imperial

College and the University of Warwick to develop a series of models, together referred to as the 'Strategic Transport and Energy Demand' (STED) model, to simulate the impacts of V2G and smart charging across the entire GB system and to understand how much could be potentially realised in 2035 and 2050.

The research considers three types of charging that can have an impact on aggregate electricity demand patterns.

- **Smart charging**, where EV drivers allow the charging of vehicle batteries adjust to price signals);
- **'Deep V2G'**, where EV drivers allow vehicle batteries to engage in energy arbitrage, for example, exporting power to the grid at peak times when prices are highest and importing power from the grid when prices are lowest; and
- **Availability for system services**, where EV drivers allow batteries to be available for the provision of ancillary services to the grid or participation in the Balancing Mechanism.

How is this problem being studied?

As part of this research, Frontier Economics has developed the Electric Vehicle Agent-Based Simulation (EVABS). This is an agent-based model which simulates residential drivers' usage and charging of battery electric cars (including autonomous vehicles) and plug in hybrid vehicles. The model runs for 2035 and 2050 with two FES scenarios: Leading the Way and System Transformation. These scenarios were chosen because they differ the most in terms of EV uptake and wider energy system changes. Modelling both scenarios provided a wide range of uncertainty over EV uptake, as well as around the development of the wider low carbon electricity system. For example, differences in the wider electricity system across the two scenarios results in different electricity price profiles.

EVABS required a physical space to be represented because it simulates journeys and interactions at charge-points. It has been based on a 40km x 40km square around Nottingham, which captures many representative features of Great Britain (GB) as well as real data on building types and driving speeds. EVABS results were then scaled up, with adjustments to account for key differences between the Nottingham area and GB to produce GB-level outputs.

Furthermore, this model drew upon two new pieces of behavioural research with outcomes summarised below:

- Range anxiety varied across drivers. This is reflected by designing EVABS to incorporate variation in drivers' preferences for minimum charging levels.
- Participants perceived some inconvenience and hassle associated with charging. This is reflected by factoring in different preferences around plugging in into EVABS.
- Some drivers worried about the impact of charging behaviour on battery degradation. In EVABS, drivers are given preferences to engage in 'deep V2G', since deep V2G is more likely to cause degradation.
- Some drivers were cost sensitive while others were not engaged with the market. EVABS includes utility functions, which allow the weight drivers' put on cost to vary, relative to other factors.

How is uncertainty reflected in the model?

There is a high degree of uncertainty associated with modelling smart charging and V2G in 2035 and 2050. The V2G technologies that are considered have not yet been taken up in the mass market and, as they are taken up, the characteristics of these technologies may change. As such, this project relies on asking consumers hypothetical questions about their behaviour and subsequently makes assumptions about technological development. Uncertainty around consumers' willingness to engage with smart charging and V2G are considered through five different sensitivities.

- The Highly Unfavourable sensitivity assumes that drivers do not install V2G-enabled chargers at home, due to high associated upfront costs. They are not willing to undertake deep V2G at public charge-points due to concerns about battery degradation, but they are happy to make their batteries available for system services, when plugged in at the 50% of public chargers

that are V2G-enabled. At home, they engage in smart charging, but they plug in only when their vehicle needs a charge, because they perceive plugging in to involve hassle.

- The Highly Favourable sensitivity assumes that technological progress has mitigated drivers' concerns about battery degradation and therefore all drivers are open to participate in deep V2G where it fits with their driving patterns and minimum charge preferences. All drivers with off-street parking have V2G-enabled chargers, as it is assumed technological progress has brought the costs down. In addition, all drivers plug in whenever they are parked near their preferred charger. This is because we assume that technological progress has reduced the hassle associated with plugging in (e.g. wireless charging is widespread).

Between these two extremes are three other sensitives which vary in assumptions on access to V2G enabled chargers, willingness to undertake deep V2G and plug in.

What impact can V2G have on peak demand reduction?

Table 3 summarises the impact on charging demand by MW during typical system peak demand hours by sensitivity and scenario i.e. System Transformation (ST) and Leading the Way (LW).

Table 3 Impact on Peak Demand (MW)

Scenario, year	Highly favourable	Favourable	Somewhat favourable	Somewhat unfavourable	Highly unfavourable
ST, 2035	-57.3	-34.1	-5.4	-2.4	-2.4
ST, 2050	-103.4	-60.1	-8.9	-5.7	-5.7
LW, 2035	-25.1	-20.0	-5.8	-3.8	-3.8
LW, 2050	-28.0	-21.1	-5.7	-2.5	-2.5

It is worth noting that there is a significant difference in drivers' engagement with V2G across the two FES scenarios:

- Deep V2G occurs when it is worthwhile for a driver to sell energy in a high price period and buy it back in a lower price period, taking into account associated energy losses with battery cycling. In Leading the Way, prices are flatter than in System Transformation (due to differences in the wider energy system, including greater availability of demand side response).
- System Transformation has 18 million EVs in 2035, growing to 29 million EVs in 2050. In contrast EV numbers actually fall between 2035 (27 million) and 2050 (21 million) in Leading the Way (due to assumptions on other forms of propulsion, ride sharing and public transport) [10]. Despite this, the contribution of smart charging and deep V2G still goes up between 2035 and 2050 in Leading the Way. This is because assumptions in FES about autonomous vehicles mean that each vehicle in Leading the Way is much more heavily utilised in 2050 and therefore requires charging more often.

Overall, the combination of smart charging and 'deep V2G' could have a major impact on peak demand in 2035 and 2050 where conditions are highly favourable or favourable, however if enabling technologies do not develop much smaller impacts may result.

Lessons Learned

A key input to the success of this project was the behavioural studies regarding use of EVs and smart charging, as it is the public's engagement with the technology that will determine the magnitude of impact EV technologies will have on peak demand.

In Australia, EVs today comprise of approximately 8.4% of new car sales whilst that in the UK is 23%. In 2023, the ratio of EVs to public chargers in the UK is 19 cars per charger, whilst Australia's ratio is

35 cars to each public charger. To add to this statistic, 41% of Australian EV drivers suggest that range anxiety and lack of public chargers were the biggest barriers to EV uptake whilst 51% suggested cost is another major barrier [11]. The impact of range anxiety on EV technology uptake in Australia, and Queensland more specifically, is likely to be greater when compared to the UK due to its large geographical area. There could be more appetite for EVs in Australia with better whole system coordination amongst transport and network providers to deliver the infrastructure necessary to incentivise faster EV uptake. In addition to this, Australia could further spur growth in EV uptake by leveraging its abundance of rooftop solar (in combination with V2G services) to help offset the demand from EVs.

Understanding the behavioural drivers associated with EV and smart charging uptake will be critical to achieving net zero goals. As such, greater engagement with our consumers is necessary to deliver holistic network solutions.

Case Study 2: Ultra-High-Voltage

What is the problem?

There is a need to substantially increase the capacity of the transmission system to enable the bulk-power flows required by a net zero power system. At least 89GW of wind and solar will be connected in 2030, with 119GW anticipated in NESO's Leading the Way FES scenario. This capacity requirement has led to substantial reinforcement plans as given in the business's Holistic Network Design (HND) and Accelerated Strategic Transmission Investment (ASTI) framework. Recently John Pettigrew, CEO of National Grid, announced the need for a "super-supergrid" (i.e. onshore transmission network of up to 800kV) in order to meet future demand, particularly from that of demand centres which are expected to increase six-fold in the next ten years alone [12].

Delivering these reinforcements will be demanding and any new infrastructure will face local objections. As such, increasing the voltage of new transmission routes to Ultra-High Voltage (UHV) i.e., greater than 400kV, may offer advantages to established technologies in existing plans.

What is the solution?

UHV circuits can transmit a greater amount of power over a longer distance than 400kV circuits reducing the volume of new lines required for Net Zero. HVDC technology in particular has several advantages as outlined below:

- Losses are lower and reactive power is not required to maintain voltage making HVDC preferable over long distances.
- HVDC has bidirectional power flow control and allows for frequency, voltage, stability, and power oscillation damping control.
- Minimal increase in short-circuit power/current with HVDC which avoids splitting the AC network.

What is being achieved in this project?

The application of these technologies can significantly increase the power transfer capability of the Great Britain (GB) transmission network to accommodate bulk offshore wind connections. This innovation project specifically develops solutions to reduce thermal constraint cost as well as environmental and social impacts, enabling renewables to be connected in a cost effective and efficient way. The project will:

- Identify strategic solutions (location and sizing) for both 765kV AC and 800kV VSC HVDC for the GB network reinforcement required, investigate system impacts on stability, control and protection, etc.
- Develop an innovative compact double-circuit tower design (maximum 50-55m high and wide) to minimise environmental and community impacts, carbon footprint and overall cost.
- Investigate potential solutions for cable sections operating at higher voltage (i.e. 765kV AC and 800kV HVDC) and the possible alternative routing solutions required to enable the deliverability of the higher voltage solutions.

- Develop a strategy to deliver the higher voltage solutions by assessing operability, carbon footprints, supply chains, resources requirement, whole life cycle cost, environmental impact and planning challenges, etc. and recommend a delivery strategy for implementation.

The proposed tower design as part of the innovation project is comparable to existing double-circuit towers in terms of dimensions, however provides 227% greater capacity than current 400kV AC routes. Current UHV solutions are twice the height and footprint of existing 400kV circuits, bringing significant consenting risk and impacts on local environment/communities.

Lessons Learned

It is worth noting that wind energy is the leading renewable resource in the UK and significant offshore wind development has fostered the fast development of HVDC and HVAC cables. Currently, offshore wind is connected radially from the grid (via onshore substations) whilst the future grid should be interconnected both within itself and to other grids. It is envisaged that offshore interconnector stations will be introduced to help reduce the requirement for HVAC connections and onshore substations. This solution for a connected future is summarised in the Holistic Network Design (HND) plan published by the ESO. The future offshore and onshore solutions proposed suggest that HVDC technology will play an increasingly important role in the transmission of electricity.

The Queensland Jobs and Energy Plan (QEJP) recognises the need for new high voltage infrastructure (i.e. 500kV) in order to support existing 275kV infrastructure and the development of pumped heat electric storage (PHES) [13]. HVDC is an alternative technology to the HVAC upgrades proposed, however there are several factors that determine whether HVDC or HVAC is advantageous over the other. For example, there is a “break-even” distance before HVDC becomes economically better. Typically, this break-even distance is around 600 km meaning HVAC is less expensive below these distances. This is because HVDC infrastructure requires investment in terminal converter stations whilst HVAC systems involve more expensive power towers and cables (which are larger in size) with increasing distances. HVAC is usually selected for medium and short-distance transmission when the benefits of HVDC may not be as apparent. As the Australian Power Industry explores more applications of ultra-high voltage long-distance transmission and interconnections between states (Queensland to South Australia for example could be at least 1600km), it is inevitable that HVDC technology will play an important role in the future power system. The Australian power industry should consider whether there is any value in adopting a similar HND model to avoid the challenges of redesigning for the grid of the future.

Future Works

It is currently a very busy time in the Net Zero Innovation Team as we finalise how to allocate the remaining RIIO-2 innovation funding for the rest of the current regulatory period. I am currently engaging with the Customer Connections team to define the problem around growing data centre demand and determine the role of innovation and whole system planning in this space. In addition to this, I am engaging with Network Rail and Leeds University to collaborate on a Railway Decarbonisation project, which looks at using battery storage technology to electrify railway with the aid of underutilised wind energy.

Project dissemination, both internally and externally, is also a key part of the role. Internal dissemination is beneficial for advocating the work the Innovation Team engages in and provides opportunities to collaborate with teams in the wider business. Recently I was fortunate enough to attend the Infrastructure Development and Delivery Leadership Day where I presented on Net Zero Innovation’s whole system strategy, current projects and future projects. I’ll be involved with other dissemination events throughout the remainder of the year, with the next event being *Mission Innovation Update*, which is open to an international audience hosted by the Department for Energy Security and Net Zero. I also plan to attend the CIGRE Paris Session in August.

Other Activities

Northern PowerGrid: Net Zero for the North

Northern PowerGrid (NPg) is an electricity distribution business supplying power to 8 million people in the North East, Yorkshire and northern Lincolnshire [14]. On March 21st, NPg hosted the *Net Zero for the North* conference where I met several representatives in the regional insights, major connections, flexibility and consumer vulnerability teams.

Key learnings are summarised below:

1. Northern PowerGrid's Distribution Future Energy Scenarios (DFES)

NPg has developed their own forecasting model which takes National Grid FES and CCC FES to produce the DFES. In addition to the four FES that are presented by National Grid, NPg produced a 'Best View' scenario which represents the most likely pathway to net zero for the North East, Yorkshire and northern Lincolnshire regions. Key characteristics of the 'Best View' scenario are summarised below [15]:

- 600,000 heat pumps installed annually by 2028 and bans on the usage of gas boilers from 2025 (and fully banned in 2035)
- A total generation mix of 15,394MW in 2050 to meet Net Zero requirements (including solar, wind and other generation types) compared to the current generation mix of 4670MW.
    - High large-scale and rooftop solar uptake i.e. 4244MW by 2030 and 9896MW by 2050
    - Wind uptake reaches 1698MW by 2030 and 4777MW by 2050
- In the 2030s, electric transport is expected to see the largest growth in contribution to peak demand before demand from electric heat becomes the greatest contributor from 2035.
- Large-scale battery storage will provide grid flexibility and back-up power for when there is limited sun and wind.

2. Progress towards Distribution System Operation through the DSO Implementation Plan

For the past 5 years, NPg has been expanding their capabilities to take on functions as a DSO. Embedding the Major Connections business into the DSO plan appears to be a critical milestone and has enabled NPg to connect renewable generation more quickly to the network through innovative, flexible solutions. Their model to deliver distribution system operation can be categorised into three pillars: Network Operation, Planning & Network Development and Market Development.

Planning and Network Development includes:

- An Open Data Portal which was launched at the start of 2023. This portal provides access to an unprecedented level of network data to stakeholders, with Application Programming Interfaces (APIs) and visualisations making the data more available and insightful. There are over 2,500 unique users utilising this portal and significant activity via APIs showing automated use of data.
- The development of digital twins to provide centralised models to inform stakeholders on planning and decision making.
- 3,300 LV monitors on the network providing smart meter data to enhance forecasting techniques and help to better understand network capacity and loading in greater detail.

Network Operation includes:

- Continual revision of connection offers to expedite applications. In the last year, 28 offers were revised to provide earlier connection dates for customers, reducing lead times by 6 years.
- NPg is developing an enterprise Active Network Management (ANM) and Inter Control-room Communication Protocol (ICCP) link, allowing ESO the visibility and control over distribution connected DER.

Market Development includes:

- Development of the flagship Community DSO project, which aims to develop new frameworks that will allow local communities and stakeholders to deploy Smart Local Energy Systems (SLES).
- The ‘stackability’ of flexibility products to allow FSPs to operate DSO and ESO flexibility products simultaneously.

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