Response to: Consultation on the proposed regulatory funding and approval framework for onshore transitional Centralised Strategic Network Plan 2 projects

Dear Ofgem,

I am writing in response to your consultation on the proposed regulatory funding and approval framework for onshore transitional Centralised Strategic Network Plan 2 projects. The technical and economic development of electricity systems, both in Britain and abroad is an interesting topic, the following are my personal thoughts on this consultation and my perceptions of the risks of the current approach.

Your consultation document neatly sets out the challenges faced by the GB transmission system over coming decades beyond 2030, however reading through the consultation document, through NGC ESO's tCSNP2 document and through supporting documents such as the Network Options Assessment (NOA) documents, what is quite surprising is the absence from all of these documents of any discussion of a key strategic topic, which based on international comparison, you would reasonably expect to be discussed and considered over this extended time frame beyond 2030.

It is the 'elephant in the room' for the future development of Great Britain's on-shore transmission network beyond 2030, arising from the changing composition and geographic location of connected generation capacity, which will require significantly greater long distance, bulk transmission of electricity across the GB transmission system.

These growing challenges and demands are new to the GB on-shore transmission system but they are not unique to Great Britain, looking outward internationally at the experience of other country's transmission networks, many have already faced these challenges and solved these problems.

When comparing internationally, one of the key tools used to meet those needs has been through the use of next generation transmission technology; transmitting power at higher voltages which allows bulk transmission of electricity in greater quantities, over significantly longer distances, using fewer circuits so requiring fewer overhead lines, with lower land use for rights of way and lower environmental impact, with lower losses, at lower cost to the consumer than "legacy" 345kV / 400kV / 500kV transmission infrastructure.

The key strategic topic is transmission voltage and the question of whether, and in what form, Great Britain might start utilising the next generation of 765kV AC and HVDC on-shore OHL transmission technology that is already in use in other countries around the world?

The strategic technology choices being made beyond 2030 will determine the future shape of the GB transmission system, the costs of the network, its capacity to connect both distant renewable generation and clusters of decarbonised (CCS equipped) generation, both now and for many decades to come as the technology choices will determine the scope for future network expansion. It will determine the scope and flexibility available to maximise GB's potential for renewable and decarbonised generation resources, all of which ultimately determine the long-term costs of electricity to British consumers.

In that context, you would expect that any form of strategic transmission network planning should be actively considering and discussing the network technology options available, to ensure the best possible outcome for British consumers. Looking internationally, 765kV AC and HVDC on-shore transmission is already in use, is being expanded or is a core part of future transmission network planning but in Britain today and in its strategic network planning beyond 2030, the consideration and discussion of adoption of these technologies is conspicuous by its absence.

The topic of transmission voltage is not a minor or unimportant engineering detail. It effectively sets the constraints on the feasible transmission capacity to move electricity around a country, which then determines the location, scale and potential technology mix of generation, setting the boundaries and shaping the long term economic development of electricity systems as a whole, both networks and generation. It is fundamental.

Before turning to the consultation questions, I want to set out some international examples of next generation 765kV AC and HVDC on-shore transmission, for a few reasons:

- To highlight that outside of Great Britain, this technology is mature, proven and is a key component of other country's electricity systems or their future network plans, being used by transmission network operators and system operators around the world, making it a credible option for consideration beyond 2030.
- To highlight the benefits of the technology as reported by international transmission network operators and system operators because these benefits are likely to be relevant to the future development of the British transmission network and to British electricity consumers.
- Together, to justify asking the reasonable question: "If all of these countries are already using or planning to use 765kV AC and HVDC in their on-shore transmission networks because of the benefits it provides, why is this topic not being openly considered and discussed as a key part of the future strategic planning for the GB transmission network beyond 2030?"
- I would argue this is both a reasonable and indeed necessary question, even if the ultimate decision is that GB will not adopt these technologies in its on-shore network, it is only by considering the full range of technology options available, that it can be demonstrated that the chosen solutions are optimal, or even reasonably efficient and represent a good outcome for British electricity consumers both now and in the future.

International Examples:

Hydro-Quebec:

Quebec province, Canada has extensive renewable hydro resources in the north and far north, but electricity demand from load centres of industry and consumers is concentrated in the south of the province. In the 1950s their engineers recognised that electricity transmission was one of the major barriers to exploiting the hydro electricity potential of the province, existing 345kV and 400kV transmission technology would have required too many transmission lines with too greater losses to be economic, impracticable to provide the electricity transmission capacity required, while 500kV transmission being developed at that time provided limited improvement.

This spurred Hydro Quebec to pioneer the development of 735kV AC transmission technology, with construction of their first 735kV transmission line commencing in 1962 and entering service in 1965. Since then, their 735kV network has grown considerably as it unlocked more distant renewable hydro resources, with large hydro generation complexes being built in the far north. For example, The La Grande Complex of hydro generators located in James Bay has an installed generating capacity of 15GW, located ~1000km / ~ 600 miles from the load centres of Montreal and Quebec City, made possible because of the use of 735kV transmission technology with its ability to move electricity economically and efficiently over the long distances required.

Hydro Quebec has been operating 735kV transmission infrastructure since 1965, 735kV lines are the main trunk circuits of their transmission network, with almost 60 years of operational experience. By coincidence 1965 was the same year that Great Britain energised its first 400kV transmission line, illustrating the established nature of 735kV technology, equal to GB's operational experience of 400kV transmission.

Hydro Quebec's pioneering work in developing and introducing 735kV transmission enabled it to develop its hydro resources, providing Quebec's citizens and its economy with some of the cleanest, lowest cost electricity supplies in the western world.

Further resources outlining the benefits of this technology are below:

An accessible history outlining the background and benefits of 735kV transmission:
https://news.hydroquebec.com/en/news/178/735-kv-transmission-line-celebrates-50-years/

Hydro Quebec Transmission website with further details and map of their network:
https://www.hydroquebec.com/transenergie/en/

United States:

A number of the US regional transmission organisations use 765kV AC transmission within their regions, the major transmission owner of 765kV network being American Electric Power (AEP) which introduced 765kV transmission in 1969, creating a 765kV network to overlay the 345kV and 138kV network tiers.

Focussing on one of the ISOs, the Midcontinent Independent System Operator, MISO serves 15 US states and Manitoba Canada and area covering 45 Million people with a system Peak Demand of ~127GW. Their existing networks use 345kV as its highest voltage tier, with that network facing the challenges of a decarbonising generation mix, growth of renewable generating capacity with a different geographic mix and greater bulk transfers required across the region served by its network.

As an independent system operator their planning and the supporting evidence are published so it is possible to see the rationale behind their decision making processes. That analysis includes the strategic considerations of technology options, including 765kV AC networks, comparing these to 345kV AC and HVDC (on-shore/OHL), weighing the respective merits of the different technical options. In their case, comparing 345kV transmission options to 765kV they find:

The benefits of 765 kV transmission over 345 kV transmission options include the following:

- Lower capital cost per MW-mile
- Lower land usage per MW-mile
- Fewer circuit miles required
- Lower energy and capacity losses

The benefits of 345 kV transmission over 765 kV include the following:

- Lower impact of contingencies

- Better suited to serve incremental needs when system change is not great

The full presentation comparing the 3 respective technology options is available on the MISO website, note that HVDC is on-shore/OHL, rather than the substantially more expensive off-shore subsea HVDC being used and proposed in GB.

MISO Presentation comparing the economic and technical merits of Legacy, 765kV and HVDC Transmission:
https://cdn.misoenergy.org/20230308%20PAC%20Item%2007%20Discussion%20of%20765%20kV%20and%20HVDC628088.pdf

MISO are currently developing their 'Long Range Transmission Planning' LRTP Tranche 2 Proposals, a key component of these proposals is the focus on introducing 765kV AC transmission: "This Tranche 2 portfolio focuses on creating a 765 kV transmission 'highway' within the MISO region to maximize value based on land use, line distances, transfer levels and costs".

Further details and the maps of the proposed 765kV lines are available in their LRTP Tranche 2 Anticipated Portfolio – from kick-off workshop, in LRTP section of website:
https://cdn.misoenergy.org/20240315%20LRTP%20Workshop%20Item%2002%20Tranche%202%20Anticipated%20Portfolio632013.pdf

India:

India's electricity system had operated as five separate regional grids, the concept of integrating the regional grids to create a National Grid was developed and commenced in 1992. India first introduced 765kV AC transmission in 2000. The interconnection of all five regional grids completed with the commissioning of the 765kV Raichur-Solapur transmission line in 2013, achieving the goal of 'One Nation'-'One Grid'-'One Frequency' and making the Indian power system one of the largest synchronous grids in the world.

The was achieved through extensive investment in both 765kV AC and 800kV HVDC on-shore transmission infrastructure, expansion which has accelerated further since. The growth of India's transmission system and its utilisation of the latest transmission technology is shown in the table below, of installed circuit kilometres for successive network plans:

India Electricity Transmission System – Installed Circuit Kilometres by Plan Year							
Voltage level	**1990** End of 7th Plan (31/03/1990)	**1997** End of 8th Plan (31/03/1997)	**2002** End of 9th Plan (31/03/2002)	**2007** End of 10th Plan (31/03/2007)	**2012** End of 11th Plan (31/03/2012)	**2017** End of 12th Plan (31/03/2017)	**2022** End of 2021-22 (31/03/2022)
765 kV	0	0	971	2,184	5,250	31,240	51,023
HVDC	0	1,634	3,138	5,872	9,432	15,556	19,375
400 kV	19,824	36,142	49,378	75,722	106,819	157,787	193,978
230/220 kV	59,631	79,600	96,993	114,629	135,980	163,268	192,340
Total (circuit—km)	79,455	117,376	150,480	198,407	257,481	367,851	456,716

(Table data - see National Electricity Plan (Draft) Volume II – Transmission, Document Page 16 (PDF Page 24))

To put those figures in context, as of 2019/20 in GB, NGET had ~14,400 circuit kilometres of OHL, SP had ~4,000 circuit kilometres (across 275kV and 400kV networks). In 2020-2022 India having HVDC network infrastructure equal in distance to the combined NGET and SP systems, with India having 765kV AC transmission network infrastructure over twice the distance of the combined NGET and SP systems.

The draft version of the next revision of India's transmission network development plan can be found on their website. India – Central Electricity Authority, web page with Draft National Electricity Plan (Volume II: Transmission) (in English):

https://cea.nic.in/wp-content/uploads/psp___a_i/2024/01/Draft_NEP_Vol_II.pdf

South Africa:

Eskom in South Africa, like Great Britain, had an electricity network system topology comprising 132kV, 275kV and 400kV tiers. In 1987 Eskom commissioned its first 765kV transmission line, with a second line converted to 765kV in 1991.

These lines formed part of a long term plan to overlay their 400kV network with a 765kV high capacity back-bone to support regional power corridors, connecting generation pools to one another and to the major load centres in the country. 765kV transmission lines providing around three times as much power capacity as a 400kV line, dramatically reducing the number of transmission lines required.

Eskom have continued the expansion of their 765kV back-bone across the country, with further expansion of 765kV transmission capacity planned.

Eskom National Transmission Company South Africa – Transmission Development Plans: https://www.ntcsa.co.za/transmission-development/

South Korea:

KEPRI in South Korea introduced 765kV transmission in 2001, constructing 3, 765kV projects upto 2009, to connect new thermal and nuclear power generation in coastal areas to load centres, opting for 765kV because of the fewer circuits required as compared to 345kV transmission, important given the mountainous terrain the routes crossed where routing and way leaves were a challenge.

The Korea Electric Power News - (CIGRE) 'Technopia of 765 kV Technology in Korea', English language article from 2009 detailing the adoption of 765kV technology by South Korea network company KEPRI:

https://www.epnews.co.kr/news/articleView.html?idxno=20645

Other countries:

To briefly summarise other countries using next generation transmission technology:

Brazil: Its transmission network uses 800kV HVDC, 600kV HVDC and 750kV AC transmission lines to connect its significant hydro generation capacity to distant load centres.

Venezuela: has a 765kV transmission network, connecting the large Guri hydro dam to the load centres on the coast.

Pakistan: is currently constructing the Dasu transmission line project, a new 765kV double circuit transmission line to connect the new Dasu Hydro Power Plant (2.16GW) to the National Grid, with 765kV/220kV substations at Mansehra and to Islamabad, a direct distance of ~115 miles.

Q1. Do you agree with our assessment of the tCSNP2 and the risks that we have identified?

What is quite striking about the tCSNP2 and the associated documents, when compared to international examples and to the historical development of the British electricity system, is that there does not appear to be much consideration or open discussion of the fundamental strategic question of whether the best long term approach to meeting future requirements is the current default strategy of on-going, incremental and piecemeal upgrading and expansion of the existing 275kV and 400kV transmission system, or whether the GB network is at a strategic turning point, requiring the adoption of a higher voltage tier to sit above the existing 400kV network; 765kV AC or on-shore HVDC transmission.

If you examine the history of the British electricity system and transmission networks, there were three key strategic turning points where the growing demands of the system had reached a point where the approach of on-going, incremental expansion of the existing networks or systems had reached its limits and was no longer optimal or cost effective, requiring a more fundamental shift in approach, adopting a higher network voltage tier as the more optimal, long term solution to provide greater transmission over longer distances, providing capacity for future growth of electricity demand and allowing scope for increased economy in power generation, allowing larger power stations, serving a wider area, sited in more optimal locations.

The first strategic turning point was building in the 1910s and early 1920s with the emerging "Diagnosis of Failure"; Britain's electricity policy framework had proved to be flawed, it had resulted in the electricity industry developing as a large number of small, largely isolated 'undertakings' each running their own miniature electricity systems. These lacked economies of scale due to the limited geographic areas and demand they served, operating smaller, less efficient generating equipment and requiring significant amounts of standby plant. Compared to international competitors like Germany and the United States which operated far larger, less fragmented systems, many (though not all) of Britain's electricity 'undertakings' had relatively high costs and their electricity prices were high, holding back adoption of electricity by industry and consumers, with electricity consumption in Britain notably lagging behind those international competitors, harming Britain's economic development.

The eventual response was the Electricity Supply Act 1926, the creation of the Central Electricity Board (CEB) and the introduction of 132kV transmission to Britain with the construction of the 132kV 'grid iron' to interconnect the larger, more efficient 'selected stations' and the loads of the numerous undertakings into regional pools, the CEB optimising and dispatching generation, with undertakings purchasing electricity from the CEB. The result, as described in technical paper "275-kV DEVELOPMENTS ON THE BRITISH GRID SYSTEM", Sayers, Forrest, Lane, 1952:

"Between 1926, when the 132-kV Grid system was planned, and 1936, when it had been in operation for several years, the installed capacity of spare generating plant fell from 70% to 26% and the average cost of generation from 0-42d./kWh to 0 19d./kWh. The Grid contributed very largely to these results and thus fulfilled the functions for which it was primarily designed,

namely the interconnection of generating stations within each area for the pooling of spare plant and concentration of generation at the more economical stations."

The second strategic turning point arrived twenty years later in the late 1940s and early 1950s, with growing electricity demand combined with advances in thermal power generation resulting in larger power station capacities, the capacity of 132kV transmission to connect larger thermal power stations located near fuel and cooling water sources,to load centres was reaching its technical limits. Advances in electricity transmission technology had also seen other countries introduce higher transmission voltages. Examining the options for the future of the GB transmission system, to quote "275-kV DEVELOPMENTS ON THE BRITISH GRID SYSTEM", Sayers, Forrest, Lane, 1952:

"the possibility of using 132-kV lines of high capacity was not excluded. However, the number of such circuits needed would be very large if their capacity with 0.4-in2 conductors be taken as 135 MVA. Wayleaves would be a major problem and satisfactory load-sharing between circuits would present serious operational difficulties. For these reasons a higher voltage appeared better for meeting even the minimum requirements, and essential for meeting the maximum requirements. Moreover, investigation showed that the cost of a higher voltage system meeting the minimum requirements would be no more, and probably less, than that of an equivalent 132-kV superimposed system."

"The decision to adopt the higher voltage thus accords with the general principle that, when a stage is reached at which development at a higher voltage is comparable in cost with development at the existing voltage, the change is invariably justified. The voltage finally selected as the highest economic value complying with the standards proposed by the International Electrotechnical Commission was 275 kV nominal, 300 kV maximum."

A decade later in the early 1960s the third strategic turning point occurred as it became apparent that the rapid growth in electricity demand would soon start pressing against the limits of the 275kV system. To quote, "THE 400kV GRID SYSTEM FOR ENGLAND AND WALES", Booth, Clark, Eggington, Forrest, 1962:

"At 31st December, 1961, the 275 kV network comprised some 1 700 route-miles of overhead line, practically all double circuit, and 46 switching and transforming stations with a total transformer capacity of 14000MVA. The actual load and generation development have made heavier calls on main transmission than were anticipated. Consumption has risen so rapidly that the demand predicted for 1965-75 will be exceeded by the winter of 1962-63. The highest growth rates have occurred well away from the older industrial areas (see Table 1), giving wider dispersal of demand, while in contrast, the accelerated generation development has become more concentrated, sometimes in unexpected locations. The 275 kV network has been developed to handle high-power transfers from the practicable generating centres to distributing centres.

While most transmission distances are short enough for 275 kV to be economical for additional lines, the associated amenity problem prompted a further study of future transmission needs, which at the end of 1960 led the Central Electricity Generating Board to proceed immediately with the introduction of 400 kV as the future voltage for main transmission."

While the decision was ultimately to adopt 400kV transmission, the paper sets out the analysis of the case for continuing the expansion of the existing 275kV network, adopting 400kV through a combination of new lines and upgrading existing 275kV lines, or a further discounted option of a 500kV network on top of a much more extensive 275kV network.

In these three examples, on-going incremental expansion of existing networks was actively considered against a strategic alternative, of breaking from incremental expansion and upgrading of existing networks to adopt the next generation of transmission technology, by constructing a new network tier operating at a higher voltage, as a lower cost, more future-proof option.

Without that weighing of the different strategic options, there is a risk that incremental, piecemeal analysis of individual, tactical, projects results in a series of decisions which while lowest cost on an individual basis, when taken collectively over a longer time frame results in a worse overall outcome. It can result in a system with insufficient capacity and future flexibility, constraining the ability to connect generation and accommodate load growth.

Looking at the developments of the 400kV system over recent years and into the future, the focus has been on incremental expansion; upgrading 400kV and 275kV line capacities, adding new 400kV lines, addressing constraints by relatively costly off-shore HVDC schemes. A long series of incremental expansions, which beyond 2030 goes well beyond 'incremental expansion', now actually into the realm of a significant re-shaping and re-configuration of the GB transmission network, reflecting the significant changes to demands on the network, as compared to its original design. But this appears to be occurring without that same kind of strategic technical analysis and discussion, that took place in the 1920s, 1950s and the 1960s and is seen taking place in other countries today, examining the requirements over coming decades and weighing all of the long term technical options available, in particular the question of transmission voltage

It raises the question, is incremental upgrading and expansion of the existing 400kV and 275kV networks, building numerous subsea HVDC schemes to bypass on-shore 400kV and 275kV transmission constraints actually the optimal long-term approach, in terms of the capacity it provides and the cost of that capacity. Will it provide adequate capacity to connect new, remote renewable generation and scope for future expansion over future decades out to 2050 or beyond? Does it include sufficient capacity and future flexibility to accommodate unforeseen changes in demand growth, in the extent or location of renewable generation, or interconnector development?

The extensive use of off-shore transmission as a means to address the inadequate capacity and constraints in the 400kV on-shore network, raises a serious question of the cost effectiveness of this approach given the high cost of off-shore transmission. Recent geo-political events involving subsea gas transmission infrastructure, where detecting sabotage was not possible prior to the asset being damaged with the resultant continent-wide impact, must also raise some serious questions regarding the security of the future GB electricity system which will have growing dependence on these subsea assets. The extended repair times of subsea assets in the event of faults or damage is also a risk, already apparent from the operational experience of the Western Link.

Taking British historical precedent and the international examples and applying them to the GB network beyond 2030, it naturally raises the question of how the current incremental approach compares against an alternative option, of adopting 765kV AC or HVDC OHL technology and incorporating this into the GB on-shore transmission network. Either by upgrading of certain existing lines, or more likely through the construction of a new 765kV or HVDC trunk, or 'backbone' transmission network to overlay parts of the existing network, designed for long-distance bulk transmission, to lift that burden from the existing, constrained 400kV and 275kV networks, releasing capacity within those existing networks for connecting new generation and accommodating load growth.

Given the large sums of capital investment resting on these decisions and the long term impact on ability to connect generation into the future, it demands an analysis of alternate strategic options, which incorporate the full range of technology options available. The existing network strategy could be characterised as a scenario 'Expand the 400kV network to the Limit', this strategy should be compared against other possible alternatives, guided by historical and international experience of network development, a scenario for the construction of a new 765kV tier; a '765kV Green Trunk Overlay' (or '765kV Green Backbone') and possibly a third scenario for incorporating HVDC into the on-shore network.

Currently Britain does not have any 765kV AC or on-shore HVDC lines or assets, the existing GB transmission owners are not experienced with these technologies, the expertise and experience is international, so there is a question of how these technologies can be brought into consideration as options for the GB transmission network beyond 2030. This needs considering at the system level, rather than at the level of individual projects or upgrades. The most likely route would be for Ofgem or ESO to approach and commission an international transmission owner or their consultancy arm, one (or preferable two) that have actual, deep expertise in designing, building and operating these 765kV and HVDC on-shore transmission networks to review the GB electricity system plans and work with ESO to develop those alternative strategic options.

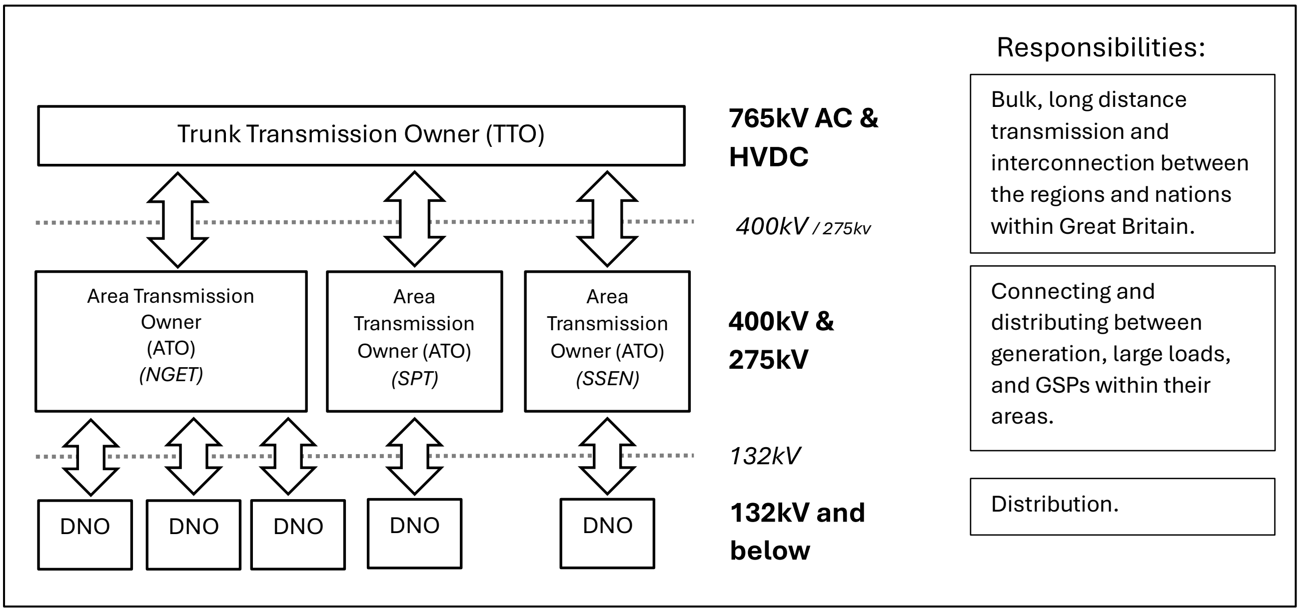
If an international transmission owner with extensive experience in 765kV AC or HVDC on-shore networks was asked for their proposals on how to develop the GB transmission network out beyond 2030, drawing on 765kV and HVDC technologies, this would then allow an assessment of whether the currently proposed incremental development of the existing 275kV and 400kV systems beyond 2030 represents a good outcome for British consumers, or whether adopting the next generation of transmission technology in some form would provide a lower cost or more future-proof alternative.

Industry structures:

The other topic which arises from the changing demands on the transmission network and the need for greater long distance bulk transmission, from Scotland and the North to the South, is that future transmission assets will cut across the geographic areas of existing organisational structures.

If building new on-shore transmission infrastructure, using next generation technology, it raises the question of whether that is best accomplished by splitting it across multiple transmission owners each developing their own plans. For wholly new trunk assets, separate from the existing infrastructure except at limited interface points to the existing networks, that may be best delivered by a new organisational entity responsible for these kind of trunk transmission assets.

Looking at the example of India, many of these new 765kV and HVDC assets have been delivered through competitive tendering, with the assets being built and operated by independent transmission companies, so it could be that there's a need for new organisation(s) which cut across the existing structures, charged with delivering that trunk network infrastructure:



British regulatory barriers prevent adoption of next generation transmission technologies:

The international examples demonstrate that 765kV and HVDC on-shore transmission technologies are established and already in use in many countries, with significant operational experience globally to demonstrate the safety and reliability of this technology.

However, currently the use of such transmission technologies in Great Britain is prohibited by the Electricity Safety Quality & Continuity Regulations 2002, Regulation 16 (2):

(2) No overhead line shall be used for the purpose of supply at a nominal voltage greater than 400,000 volts.

It seems unlikely that Great Britain should be uniquely unable to use these more advanced technologies, or there will be any inherent, or insurmountable reason why it should not be possible to remove this prohibition in future, but there will be a range of activities; technical investigations, stakeholder engagement, determination and drawing up of minimum technical, safety and environmental requirements for new overhead lines operating at 765kV AC and HVDC above 400kV, and this would need to be completed before this prohibition could be removed, to allow new OHL assets operating above 400kV to be considered or proposed. These activities all take time and would need to occur early to provide the technical parameters required as inputs into the specifications and designs for new projects and assets.

Given the time required, if not already underway, this topic needs consideration as soon as possible and Ofgem in conjunction with DESNZ, really ought to be actively working on this and kicking off the process to establish what is needed to remove this prohibition to ensure that future network planning can consider all, globally available technical options.

While this prohibition remains in place, British transmission network technical options are unnecessarily and artificially constrained, with British electricity consumers unable to benefit from the technological innovation and advancement occurring outside our borders, which appears to have the potential to provide new transmission capacity in greater quantity and at lower unit cost than 400kV infrastructure,