nationalgrid
The power of action.

National Grid Input into UK Offshore Energy SEA

Impact on Onshore Electricity Transmission System

Issue	1.0
Date of Issue	December 2008
Prepared by	Ivo Spreeuwenberg
Approved	Andrew Hiorns

Table of Contents

This document was produced as part of the UK Department of Energy and Climate Change's Offshore Energy Strategic Environmental Assessment programme.

Executive Summary

Background

National Grid has undertaken a feasibility study at the request of DECC to inform the UK Offshore Energy Strategic Environmental Assessment (SEA). The study investigates the potential impact with regard to the need for and cost of providing additional capacity on the onshore transmission system to connect a further 25GW of offshore wind generation in addition to the 8GW already planned. This level of offshore wind is, in part, required to facilitate the 2020 renewable energy target.

The study has demonstrated that, against the agreed scenarios forming the basis of studies undertaken, the onshore electricity transmission system can be developed to accommodate this level of offshore wind generation consistent with meeting the renewables target provided appropriate investment is undertaken in a timely manner. However, it is also clear that a level of coordination and collaboration would be beneficial if the required onshore network investment is to be delivered in an economic and efficient manner with a minimal environmental impact, whilst enabling offshore wind generation to make a significant contribution towards these targets.

Cost of Onshore Reinforcement

The cost of reinforcement to the onshore transmission system required for the connection of offshore wind generation will, on average, only be a small portion of the total cost of the networks required to connect this generation (10 - 20%)[1]. The cost of undertaking the onshore reinforcement therefore has much less of an effect on the overall costs than those of the offshore assets required, such as sub-sea cabling and offshore platforms. Generally it is the timescales for building new onshore transmission capacity along with the visual impact of the equipment that will have the most significant effect on the connection of offshore wind generation.

Planning and Offshore Regulatory Regime

The Planning Bill, which received Royal Assent on 26 November, is seen as an essential process to enable significant energy infrastructure projects to be constructed, while enabling local communities and stakeholders to fully engage in the development process. However, lead times for completion of onshore transmission reinforcement are likely to remain longer than those for offshore transmission.

The majority of the analysis for this study was undertaken on a set of electricity generation and demand background assumptions agreed with the Department of Energy and Climate Change. The first, referred to as the 'Non-Contractual Scenario' allowed a range of future possible outcomes to be studied rather than simply performing the analysis on a background with all the generation which is contracted to connect, as is currently done for any connection application received by National Grid. In conjunction a second scenario, the 'Contracted Background' was also analysed with a range of sensitivities considered. These backgrounds are summarised in attachment 7 as figures 1&2 respectively.

In order to assess and quantify the onshore impact of connecting 25GW of offshore wind generation, a number of assumptions were also made regarding the location of future offshore wind farm developments. These assumptions, shown in Table 1 below, were based predominately on water depth, but were also influenced by areas of the sea bed where developers have shown

[1] Round 3 Offshore Windfarm Connection Study, 18th December 2008, The Crown Estate

interest through the Crown Estates map. This map is included in Attachment 3. Of note is the fact that no offshore wind generation was assumed to locate in Regional Sea 3 – Eastern Channel; due to developer interest in this region connection sites are investigated.

Table 1: Assumed Regional Sea Capacity		
Regional Sea		Assumed Offshore Wind Capacity (GW)
1	Northern North Sea	2
2	Southern North Sea	16
3	Eastern Channel	0
4	Western Channel & Celtic Sea	2
5	Atlantic Southwest Approaches	0
6	Irish Sea	5
7	Minches and Western Scotland	0
8	Scottish Continental Shelf	0
	Overall Total (GW)	25

Impacts on the Onshore Transmission System

Based on these input assumptions, the impact on the onshore transmission system as a whole was analysed. The indicative, major system reinforcement requirements and the potential timescales for realising these are shown below in Table 2. This table shows the overall 'wider system impact' of connecting 25 GW of offshore wind. It should be noted that where onshore reinforcements are identified, environmental impact assessments have not been carried out at this stage. Prior to undertaking any onshore reinforcements environmental impact assessments will be undertaken in accordance with best practice against a range of possible solutions.

The impact at local connection points (i.e. substations) was assessed separately and is discussed below. However, the planning consents process may link overhead line and substation work so that it may not be possible to progress one without the other.

Table 2: Major Onshore Reinforcements Identified with Long Lead Times*				
Regional Sea		Major Wider System Reinforcements	Potential Timescales	Indicative Cost
1	Northern North Sea	Currently being assessed as part of the collaborative transmission owner study		
2	Southern North Sea	400kV overhead line (OHL) from Grimsby West to Walpole substations	6 – 7 years	£320m
		400kV OHL Walpole to a new substation near Peterborough on the Cottam-Eaton Socon line	6 – 7 years	
		400 kV OHL Creyke Beck to Drax substation (or new 400 kV overhead line from Killingholme to West Burton substation)	6 – 7 years	
		Rebuild Bramford substation + new section of OHL from Bramford to Twinstead	5 – 6 years	£170m
3	Eastern Channel	None against scenarios investigated (potential interaction with nuclear replanting at Dungeness in this region)	-	-
4	Western Channel & Celtic Sea	None against scenarios investigated (potential interaction with nuclear replanting at Hinkley Point in this region)	-	-

6	Irish Sea	Second circuit on existing OHL between Pentir and Trawsfynydd	5 – 6 years	£190m

*Environmental Impact Assessments have not been undertaken at this stage

It is clear from the information in Table 2 that the timescales associated with major onshore reinforcements could have a significant effect on the timing of the connection of offshore wind generation. Given the time within which these developments will have to connect if they are to contribute towards 2020 renewable targets, some onshore reinforcements may have to occur prior to individual projects coming forward for connections to the system.

1.

Figure 1, below illustrates at a high level the assumptions on time to achieve planning consents and undertake construction included as part of the potential timescales indicated in Table 2. The assumption on planning consents is that most likely to vary and could have a negative impact on overall timescales should they be extended.

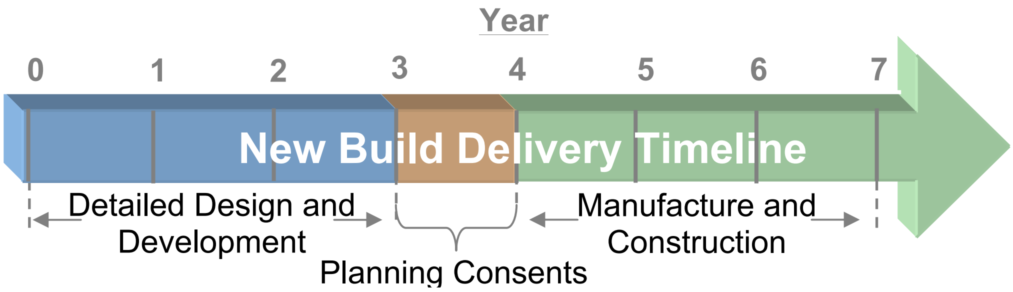


Figure 1 – Break Down of Project Delivery Timeline

In assessing the onshore impact at local connection points, the potential for a significant amount of substation work was identified at some sites. The majority of this work is associated with the offshore transmission system. In particular, potential offshore areas for development that are a significant distance from the onshore connection point would require the use of HVDC technology[2] for economic connections, given existing and foreseen technologies. In this case each 1.1GW connection will require 2 cables to come to shore and an HVDC converter at the onshore interface point in addition to the 2 transformers required to connect to the 400kV onshore system. At some of the sites identified through the design optimisation process, 2 or 3 of these converters will be required with a footprint of approximately 125 x 95m and building height of approximately 24m.

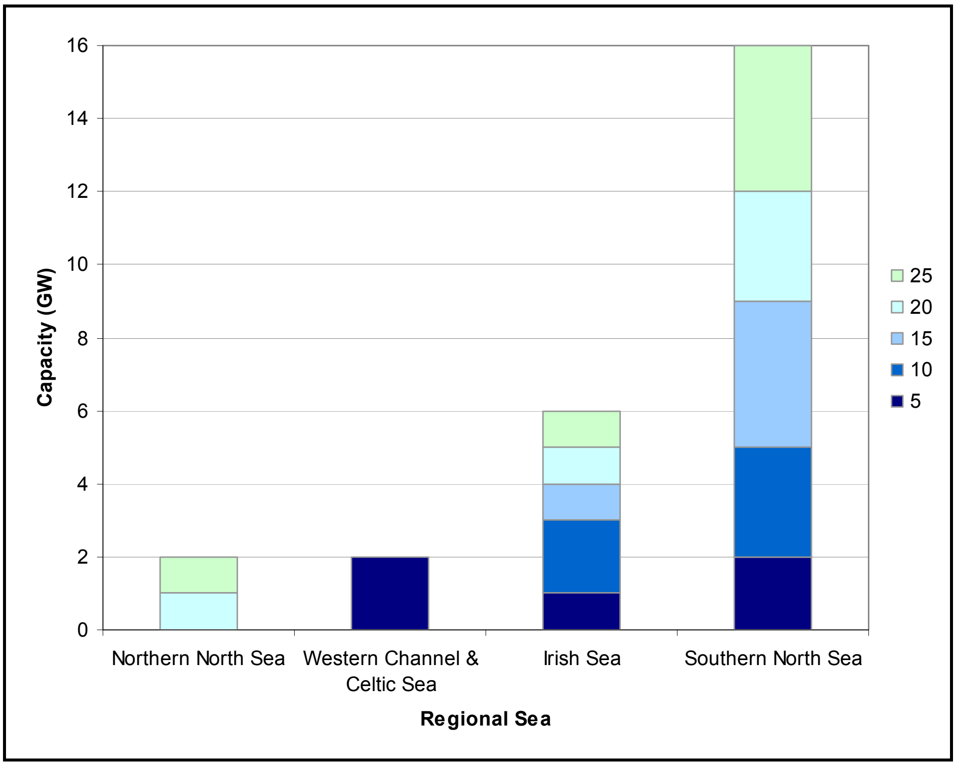
Building on the wider system impact based on the assumed geographic dispersal of offshore wind projects and the site-by-site investigation of potential connection points, a possible build-up or Round 3 wind was developed for illustrative purposes. This build-up, shown in Table 3, assumes that a total of 25GW will be developed within a limited period of time and that sites closer to the shore, and therefore more economic to develop, will be developed first. This potential build-up is shown below.

[2] Current design proposals have assumed that Voltage Source Converter - High Voltage Direct Current (HVDC) technology would be required and that this technology will develop to facilitate power transfers of up to 1.1GW.

Table 3: Potential Build-up of Round 3 Used in Assessment								
Regional Sea		Area	Offshore Incremental Installed Capacity (GW):					Regional Sea Total (GW)
	Overall Total (GW) Installed		5	10	15	20	25	
1	Northern North Sea	Moray Firth	0	0	0	0.5	1	2
		Firth of Forth	0	0	0	0.5	1	
2	Southern North Sea	Dogger Bank	0	0	3	4	8	16
		Greater Wash	1	3	3	3	3	
		East Anglia	1	2	3	5	5	
3	Eastern Channel	South Coast	0	0	0	0	0	0
4	Western Channel & Celtic Sea	Bristol Channel	2	2	2	2	2	2
6	Irish Sea	North Wales	1	2	3	4	4	5
		North West	0	1	1	1	1	

From the potential build-up, the incremental impact of connecting 5, 10, 15, 20 and 25GW of offshore wind generation was assessed. This report highlights only those reinforcement requirements arising as a consequence of offshore wind generation projects, as opposed to those driven by the power flows arising from overall system conditions. This is useful for illustrative purposes and as an aid to assessing the impact of the offshore wind developments on the onshore transmission system in isolation. However, given the non-linear nature of the interconnected electricity transmission system, the separation of reinforcement requirements between individual developments should not be considered a wholly accurate representation.

In Table 4, below, the major reinforcement requirements identified by this study are summarised against the assumed build-up. Given the typical 'new build delivery timeline' illustrated in Figure 1 – Break Down of Project Delivery Timeline and the 'notional years' given to the build-up in Section 4 of this report, an onshore development initiation date is provided. This date illustrates when detailed development of the major onshore reinforcements (such as new overhead lines and new substations) may need to be initiated. These dates are purely indicative based on the build-up scenario and will vary depending on the time required to obtain the necessary planning consents, availability of system outages to undertake work and any increased lead times arising from supply chain constraints.



Total Capacity (GW)	Major Incremental Reinforcement Requirements*	Onshore Development Initiation
	Table 4: Illustrative Build-up of Reinforcement Requirements	
5	• Minor system impact (assuming OHL reconductoring already planned is completed)	-
10	• Several minor reinforcement schemes including OHL reconductoring (i.e. upgrading) + new Bramford substation • Second Pentir to Trawsfynydd OHL on existing route	2009
15	• New Bramford to Twinstead OHL	2009
20	• New Grimsby West to Walpole + new Walpole to 'Cottam – Eaton Socon' route OHL	2010
25	• New OHL routes triggered by 'local reinforcement' requirements	2011

* To be used for illustrative purposes only

The design and cost of the offshore transmission system has not been investigated in detail as part of this study. Rather, pragmatic assumptions were made about the technologies likely to be used, which has allowed for a high-level assessment of the likely visual and environmental impact of this equipment to be made. These assumptions are broadly consistent with offshore transmission network requirements identified in the 'Round 3 Offshore Wind Farm Connection Study' commissioned by the Crown Estate.

Throughout this analysis it is assumed that the offshore network will develop in an optimised fashion, minimising the amount of equipment required for connection. Under Round 3, successful bidders in The Crown Estate leasing process will acquire exclusive rights to develop wind farms in specified zones.

1. Introduction

Offshore Energy Strategic Environmental Assessment (SEA) for Offshore Wind Leasing

1. This work specifically investigates the impact on the onshore electricity transmission system of connecting up to a further 25 Gigawatts (GW) offshore wind generation capacity by 2020. The study is limited to consideration of offshore wind generation within the UK Renewable Energy Zone and the territorial waters of England and Wales where the water depth is 60m or less as shown in Figure 2, below, which was taken from the SEA scoping document published in December 2007. A separate SEA process for offshore wind will be undertaken by the Scottish Executive for territorial waters surrounding Scotland[3]. This report outlines the second phase of work undertaken by National Grid to inform the UK Offshore Energy SEA.

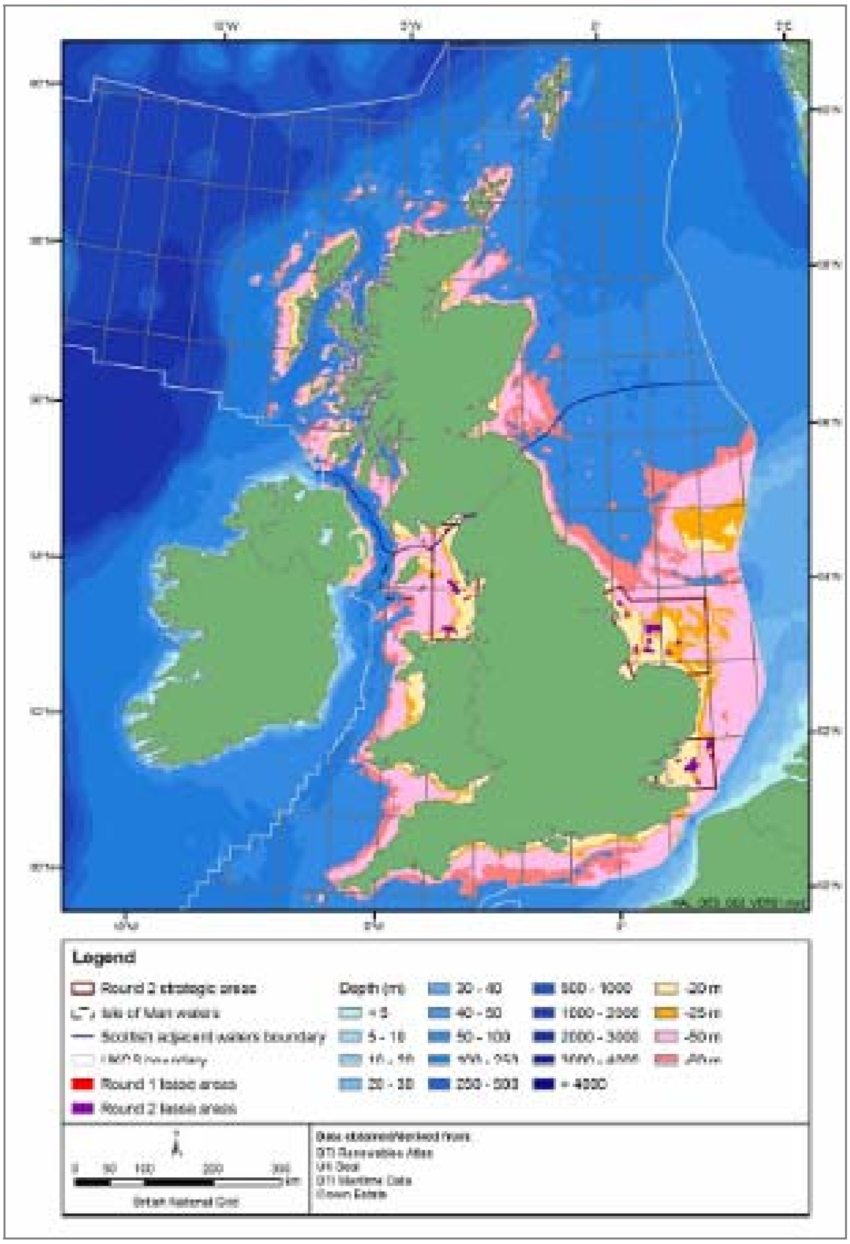


Figure 2– Existing Offshore Wind Generation Leases and Shallow Waters

[3] Announced on the 29th of October, 2008

Terms of Reference for the Study

2. The first phase of work, completed in the summer of 2008, sought to illustrate the limits to existing capacity on the electricity transmission system through high-level analysis carried out against two scenarios (identical to those used for the second phase). The results of this analysis were shown in diagrammatical form, similar to the 'connection opportunities' diagram included in the National Grid Seven Year Statement.

3. In this second phase, feasibility studies were undertaken across a number of onshore connection sites for offshore wind projects across the coast of Great Britain. In order to narrow down the large number of possibilities, a scenario was developed estimating the potential size and location of these projects, based on information sources such as water depth, and taking into account the "Indicative Economic Potential for Offshore Wind" map produced by The Crown Estate (included as Attachment 2).

4. Two scenarios were developed; one based on the contracted background[4] and a further scenario (referred to as the non-contractual scenario). The objective was to identify and outline the specification for necessary transmission reinforcements. These reinforcements encompass both the 'local connection work' for individual connection points and 'wider system work' for the incremental impact on the interconnected onshore transmission system associated with the connection of varying levels of offshore wind generation. The visual and environmental impacts of the reinforcements identified are defined in terms of a standard set of 'building blocks' that together are required for the expansion of an electricity transmission system to accommodate the connection of offshore wind generation. These 'building blocks of electricity transmission' are included in Appendix 1.

5. The purpose of this feasibility study is solely to inform the SEA for offshore wind leasing and any subsequent government decision by providing an indication of the impact of connecting offshore wind generation to the onshore transmission system. Therefore, this study in no way constitutes an SEA for onshore electricity transmission.

Methodology

6. The impact on the onshore transmission system was investigated against a range of scenarios and sensitivities in terms of both the local reinforcement work required at the onshore connection point and the wider transmission system reinforcements required as a result of a change in the flow of electricity on the onshore system arising from the connection of offshore wind generation.

7. In order to inform which onshore coastal electricity transmission substations were potential connection points, offshore locations for wind generation projects were identified using a number of assumptions based predominately on water depth and a high level assessment of several other 'hard constraints' offshore[5]. The onshore substations were then investigated individually in terms of the impact of connecting offshore wind generation.

8. By modelling the assumed distribution of 25GW of offshore wind into a power systems analysis package, the impact on the overall, interconnected transmission system could be ascertained. These impacts are articulated in terms of substation extensions, overhead lines, etc., all of which are explained in detail in Appendix 1.

9. One possible scenario for the build-up of the offshore wind generation, assuming a final target of 25GW in addition to the 8GW planned for Round 2, was then analysed in Section 4.

---

[4] Comprised of all those users of the electricity transmission system having bilateral connection agreements with National Grid

[5] Such as shipping lanes and oil and gas infrastructure

2. Scenarios

10. The onshore electricity transmission system, as it exists today, has been built up over a period of time around the prevailing generation and demand background. It takes the electricity produced by generators across Great Britain and transmits it over large distances to points where the lower voltage, distribution networks take it further to the actual demand consumers. The transmission system is designed to ensure that electricity demand can be supplied at times of peak load and to facilitate competition in the electricity market in an economic and efficient manner.

Background Assumptions on Generation and Demand

11. In planning future onshore transmission capacity requirements, the outcome of the assessment is highly dependent on the generation and demand pattern assumed (this is explained in greater detail within Appendix 3 – Planning Transmission Capacity). In addition, the further one looks towards the future, the more uncertain the likely generation and demand pattern becomes. Therefore it is general practice to develop a scenario that represents one possible future outcome for analysis as well as to undertake an investigation of various sensitivities around this scenario to identify the effects of a change in these assumptions.

12. Two distinct scenarios have been investigated as part of this work. Each scenario includes projections of existing and new-build generating plant and forecast peak electricity demand. Both scenarios include large volumes of wind generation. However, only the 'Non-Contractual Scenario' achieves the assumed level of between 35 and 40% of electricity to be provided from renewable sources by 2020/21 which is consistent with meeting the 15% of all energy met from renewables target presently being considered in the draft EU Renewable Energy Directive.

13. In essence, the non-contractual scenario forms the basis for this phase of work (Phase 2). In addition, a range of sensitivities, including a 'contracted background' scenario, have also been analysed to ensure the conclusions reached are robust against a range of possible future outcomes.

Non-Contractual Scenario

14. The non-contractual scenario was originally developed as part of a range of scenarios to be utilised by National Grid in investigating future requirements of the onshore transmission system in Great Britain. One version of this scenario is also currently being utilised as a base case in the collaborative, transmission owner studies currently being undertaken under the auspices of the Electricity Networks Strategy Group (ENSG) (see below).

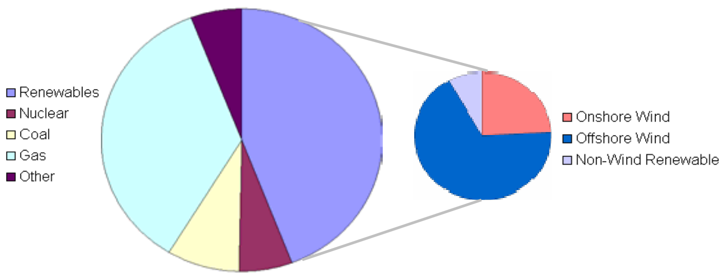


Figure 3 – Non-Contractual Generation by Fuel Type Summary

15. Figure 3, shows an example of what the electricity generation mix could look like should a large proportion of this generation originate from renewable sources (approx. 40%), with a significant amount being provided by offshore wind. The scenario also assumes that the

proportion of electricity generated from coal might reduce, with new 'Clean Coal' technologies replacing all existing coal generators on the system to form only a small portion of the total. In addition, it was considered that gas fired generation could continue to play a large role in a world with large volumes of renewables.

16. A view on likely plant closure dates based upon age and economic viability in a competitive generation market is also taken into account in the production of this scenario. It is anticipated that many of the existing nuclear stations may have retired. The scenario assumes that 2 new units will be constructed (i.e. 3.2GW) by 2020. Sensitivities addressed in the study will include the possibility of further nuclear connections; particularly where these could affect the system requirements for the connection of further rounds of offshore wind. In addition it is assumed that the majority of onshore transmission connected wind will connect in Scotland. Currently there is insufficient transmission system capacity available to facilitate this level of wind generation in Scotland.

17. Projected peak demand levels also play a role in the scenario assumptions. In the non-contractual scenario demand is expected to decrease by approximately 8% to 56.3GW by 2020, reflecting the potential impact of energy saving measures and an increasing contribution of small, embedded generation projects.

Electricity Networks Strategy Group (ENSG)

18. The Electricity Networks Strategy Group[6] (jointly chaired by DECC and Ofgem) has instigated a collaborative study that will develop a 'vision' for the electricity network for 2020 and beyond. The study, led by National Grid and the Scottish Transmission Companies working closely with broad representation from the wider electricity supply industry seeks to identify the transmission reinforcements required to facilitate the 2020 renewable targets.

19. At the time of writing the ENSG study is still ongoing and it is anticipated that initial results will be available in early 2009. Therefore, in order to progress this report, the scenarios investigated have assumed that all transmission reinforcements currently planned or under construction are completed and subsea links between Scotland and Enlgand on both the West and East coasts are established. The sensitivity of not having these links in place was also considered, which concluded that this assumption does not have a significant impact on connections in England and Wales.

20. It should be noted that this scenario was developed to test the range of required transmission system capacity, and does not necessarily reflect the views of either the onshore transmission owners or the ENSG on the specifics of any likely openings and closures of power stations or the optimal approach to system reinforcements.

Contracted Background (SYS 2008 Background) Scenario

21. The generation and demand pattern utilised for the 'contracted background' is that of the final year of the 2008 National Grid, Seven Year Statement (i.e. 2014/15) with the demand scaled upwards at an average rate along the established trend out to 2020. The generation in this scenario are all projects that have a bilateral connection agreement with National Grid as at December 2007. Any system reinforcements necessary for the connection of this generation are assumed to be in place. Therefore it is only the incremental reinforcement requirements as a result of connecting offshore wind energy that have been identified in this report.

22. The Contracted Background Scenario only considers those closures for which a formal notified closure announcement has been made (e.g. for Magnox nuclear) or where there is a recognised closure date (e.g. LCPD opted-out plant). Accordingly, this scenario results in very large plant margins (total installed generation capacity as a percentage of peak electricity

[6] http://www.ensg.gov.uk/

demand) relative to the non-contractual scenario. Under this scenario there are no further nuclear closures to those considered above.

23. An *export* from the Great Britain transmission system to France at the time of peak electricity demand is assumed under the Contracted Background Scenario, whereas under the non-contractual scenario an *import* from France at times of peak electricity demand is assumed. Both scenarios have assumed a net flow of zero across the BritNed interconnection between Great Britain and the Netherlands. Sensitivities of greater interconnection are also considered, as described below under 'sensitivities'.

Potential Onshore Connection Points for Offshore Wind Energy

24. A range of coastal electricity substation sites have been considered which were deemed likely to be suitable for the connection of offshore wind generation. A list of sites was collated utilising knowledge of the onshore transmission system from the onshore transmission owners and likely offshore development areas based on the simple criteria of water depth and a range of other sources including The Crown Estate map included in Attachment 2.

25. Sites considered as part of this study are shown in Table 5, below:

Table 5: Sites Considered for Connection of Offshore Wind Generation

Regional Sea 1	Regional Sea 2	Regional Sea 3	Regional Sea 4	Regional Sea 6
• Lintmill • Blackhillock • Peterhead • Arbroath • Tealing • Cockenzie • Torness • Branxton	•Thornton •Drax •Keadby •Creyke Beck •Killingholme •Grimsby West •Walpole •Norwich Main •Sizewell •Bramford •Rayleigh Main •Barking	• Chickerell • Bolney	• Alverdiscott	• Heysham • Stanah • Deeside • Pentir • Wylfa

Potential Locations for Future Offshore Wind Energy

26. Utilising data on which areas of the seabed within the Renewable Energy Zone are less than 60m in depth, provided in Attachment 1 and a range of sources indicating the potentially feasible locations of further offshore wind generation projects, a scenario for possible distribution across the various offshore regions was put together. This distribution of a total of 25GW of offshore wind generation, additional to the approximately 8GW already planned, is shown in Table 6 below. This locational distribution scenario is utilised throughout the study to assess the onshore impact of connecting offshore wind.

Table 6: Potential locations for further rounds of wind leasing up to 25GW

	Regional Sea	Area	Area Installed Capacity (GW):	Regional Sea Installed Capacity (GW)
1	Northern North Sea	Moray Firth	1	**2**
		Firth of Forth	1	
2	Southern North Sea	Dogger Bank	8	**16**
		Greater Wash	3	
		East Anglia	5	
3	Eastern Channel	South Coast	0	**0**
4	Western Channel & Celtic Sea	Bristol Channel	2	**2**
6	Irish Sea	North Wales	4	**5**
		North West	1	
Overall Total Installed Wind (GW)			**25**	

27. The distribution shows that for a total installed offshore wind generation capacity of 25GW, almost 65% (16GW) of this is projected to come from projects located in the Southern North Sea (i.e. Regional Sea 2) based on the aforementioned input assumptions. A change in the assumed distribution of generation will effect the onshore reinforcement requirements and their timing.

28. One scenario of the possible build-up of offshore wind capacity up to 25GW is investigated in Section 4. This section seeks to indicate the onshore impact of connecting a total of 5, 10, 15, 20 and 25GW of offshore wind, assuming that a total 25GW is the final target.

29. Figure 4, below, illustrates a representation of the relative size of offshore wind generation capacities spread across the various Regional Seas as shown in Table 6, above. It is clear from this representation that a significantly large proportion of the 25GW is concentrated in two areas. Given this disposition of offshore wind generation, it is likely that these areas of the onshore system will be impacted the most and may therefore require the largest amount of reinforcement to facilitate the transmission of the electricity generated to the demand centres where it will be consumed across Great Britain.

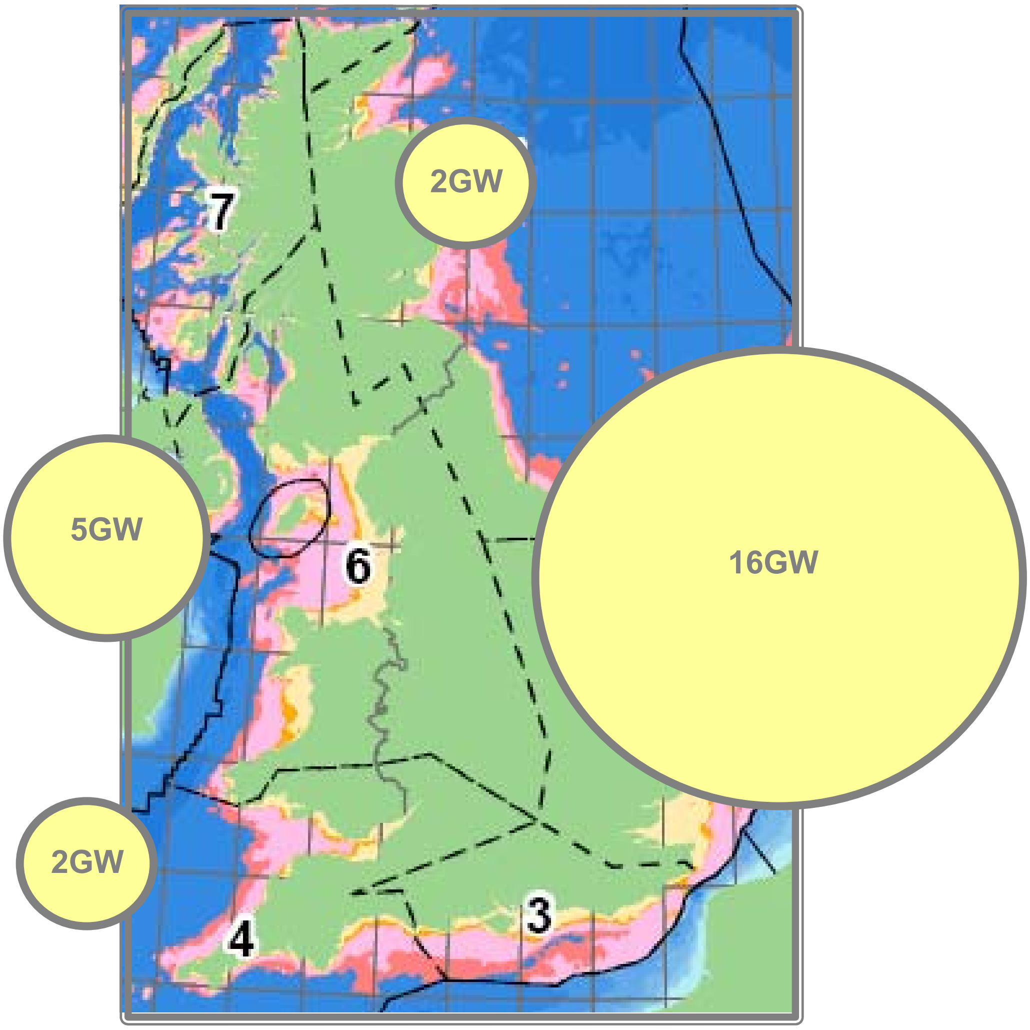


Figure 4 – Illustration of Potential Offshore Wind Distribution

Sensitivities

30. As mentioned above, electricity transmission system reinforcement requirements are heavily dependent on the power flows that arise on such a system due to both the size and location of generation and demand. This is explained in more detail within Appendix 3 – Planning Transmission Capacity. As the exact generation and demand patterns utilised in this analysis have a low probability of occurring exactly as modelled, several sensitivities have been considered and are discussed throughout the results commentary, which gives an indication of the potential impact of these alternative futures. Some of the changes that could have a significant impact are outlined, below.

Gas and Coal Fired Generation

31. In order to facilitate large volumes of generation with a variable output such as wind, large volumes of flexible conventional plant will need to materialise to support this. Therefore, the potential for large volumes of new and replanted gas fired generation in the North East and South Wales as well as Clean Coal and CHP projects are also taken into account.

Nuclear Generation Connections

32. The Government will undertake a Strategic Siting Assessment (SSA) in 2009, to assess nominated potential locations for their suitability for the deployment of new nuclear power stations by 2025. This exercise is being accompanied by a Strategic Environmental Assessment (SEA).

33. The Government noted in the Nuclear White Paper that it expected that nominations to build new nuclear power stations would focus on areas in the vicinity of existing nuclear facilities. This reflected an indication from industry that these are the most suitable sites. The impact of replanting these is therefore considered in the commentary of the results section. New nuclear generation with a bilateral connection agreement in place for connection to the onshore transmission system are shown in Table 7, below.

We recognise that the suitability of any site will need to be assessed through the Strategic Siting Assessment process.

Table 7: Contracted Nuclear Generation

Station	Size	Contracted Date[7]
Bradwell B	1650MW	2016
Dungeness C	1650MW	2016
Hinkley Point C	3300MW	2016
Sizewell C 1	1650MW	2016
Sizewell C 2	1650MW	2021
Oldbury-on-Severn	1600MW	2020

34. Other sites with existing or decommissioned nuclear generation considered in this study include Wylfa and Heysham. The locations of these sites (which form a non-exhaustive list) are illustrated against the Regional Seas map in Figure 5, below.

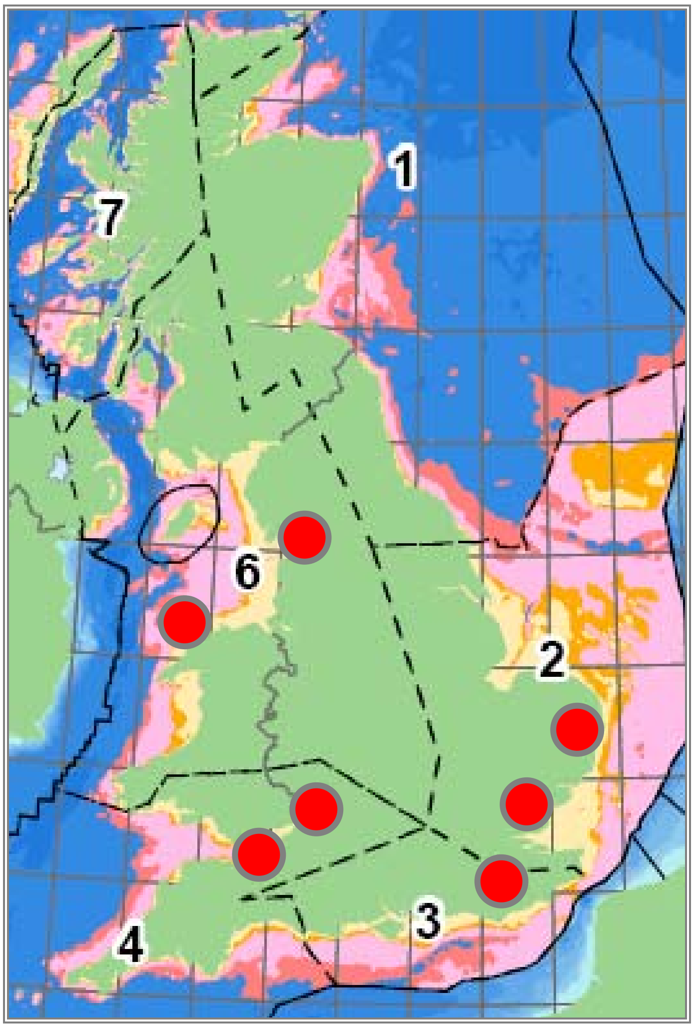


Figure 5 – Illustration of Potential Nuclear Replanting Sites

[7] Contracted position as at September 2008

International Interconnections

35. The following interconnectors have been taken into consideration either as part of the scenario or as sensitivities in this study:

- Moyle Link
- French Link
- East-West Interconnector
- BritNed
- Link to Norway

36. This consideration is reflected in the location of potential onshore connection points considered (outlined in Table 5) and the potential reinforcement requirements identified.

37. The location of these links is illustrated in Figure 6, below.

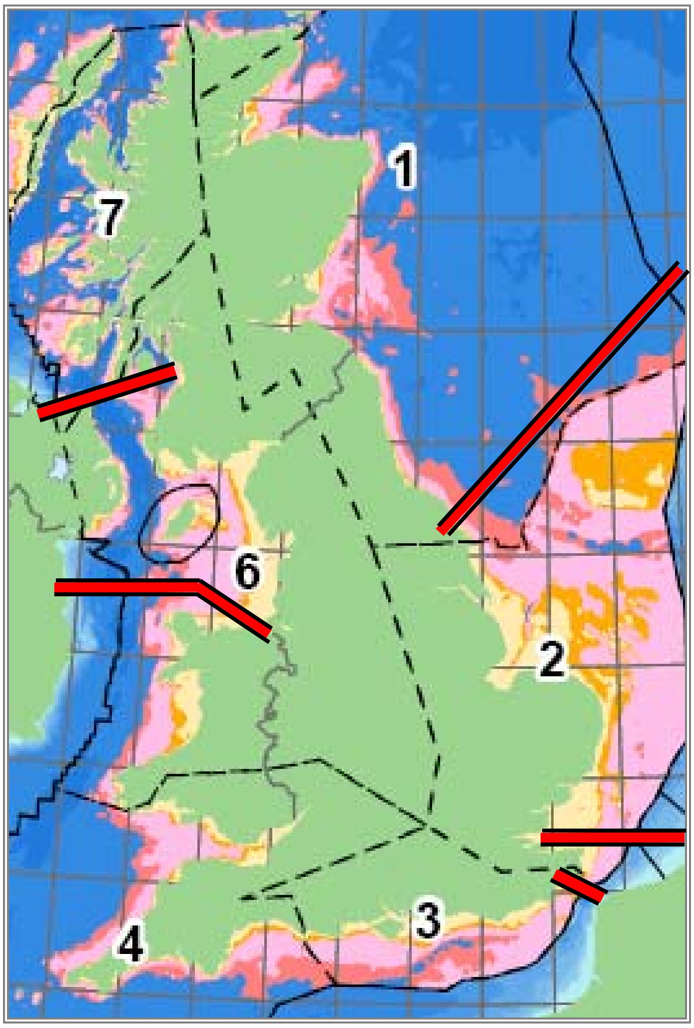


Figure 6 – Illustration of Potential and Existing Interconnectors

Other Marine Renewables

38. Potential for tidal development in the Severn Estuary was not considered in this study as a detailed feasibility study is currently under way in which National Grid is participating. Should one of the larger tidal scheme proceed, which could be over 8GW in capacity, there would be significant impact on the surrounding transmission system, particularly if this was to occur alongside new nuclear development at Hinkley Point and/or Oldbury.

39. The Pentland Firth is also considered an area that is ideal for development, due to the tidal and wave power available in this area. The Crown Estate has announced (end of September 2008) an application process for commercial sea bed lease options in this area. However, the development timetable quotes 2010/11 for the anticipated deployment of first demonstration devices in the Firth. Therefore this study does not consider the possibility of large scale development of this area within the timeframe considered.

Assumptions

Review of Industry Frameworks

40. The development of transmission reinforcement requirements, including the cost and timing of these, has been produced against a backdrop of the current regulatory and commercial frameworks in place within the electricity industry. The relevant aspects of these are explained at a high-level within Appendix 1.

41. In order to help facilitate the volumes of renewable generation required to meet government targets, significant changes to these frameworks are currently being considered through several initiatives such as the reviews of transmission access arrangements and the planning standards (GB Security and Quality of Supply Standards – GBSQSS). The outcomes of all these initiatives, explained further in '*Initiatives Currently Underway'* below, have the potential to affect the conclusions arising out of this analysis. In addition, many of the issues under review are interactive as depicted below in Figure 7.

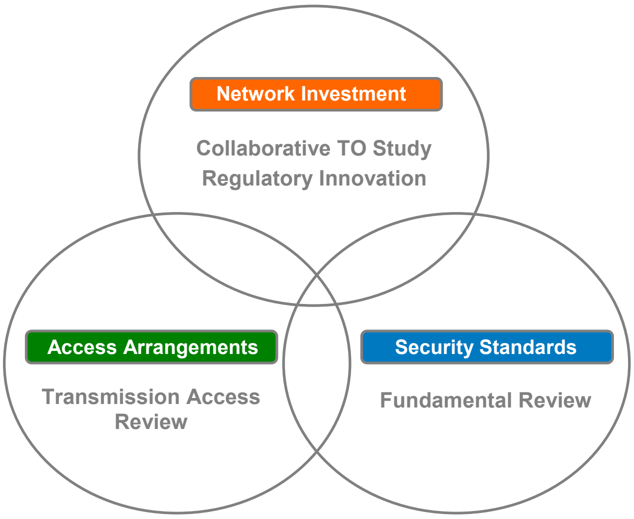


Figure 7 – Interactivity of Current Initiatives

42. As far as possible, the conclusions reached as a result of the analysis undertaken have been presented in a manner that is as neutral to the effect of these changes as practicable. However, there are elements of the work, such as the power systems analysis undertaken, which was completed against the current planning standards, that could eventually change. Nevertheless, the impact of these elements on the overall conclusions is considered to be minimal.

Reinforcements Assumed Completed

43. There are several major transmission system reinforcement schemes currently in the later stages of development or already underway for the connection of onshore wind generation in Scotland, Rounds 1 and 2 offshore wind and various connections of conventional generation. These have been assumed as being completed prior to any Round 3 offshore wind generation projects being ready to export power onto the onshore transmission system.

44. Between 6.6 and 11.4 GW of onshore wind generation has been considered to connect in Scotland by 2020. Currently, the onshore transmission system is unable to transmit the electricity generated by such large volumes of generation down into England where the majority of demand for electricity is located. The three onshore transmission owners; National Grid Electricity Transmission (NGET), Scottish Power Transmission Ltd. (SPT) and Scottish Hydro Electric Ltd. (SHETL), are currently taking forward a collaborative study under the auspices of the ENSG, that is looking at how the transmission system might need to be developed in order to facilitate the higher levels of generation needed to meet the government's renewables targets. This work is described further within Section IV – 'Current Initiatives Underway'. The study underpinning this document has not sought to pre-empt the outcome of the aforementioned collaboration and has made the assumption that the necessary reinforcements from Scotland into England are already in place. The impact of the need for these reinforcements on the connection of further rounds of wind leasing is predominately limited to those wishing to connect offshore in Scotland, north of this critically congested part of the network.

Development of the Offshore Regulatory Regime

45. Work on development of a regulatory regime for offshore generation connections with Ofgem and DECC has been underway since late 2006. This work is now at an advanced stage with the penultimate consultation on the legal text of the relevant codes having taken place in November 2008.

46. When this regulatory regime goes 'live' in 2010, all electricity equipment located offshore at a voltage of 132kV or above will be deemed 'transmission' and as such require a transmission licence for its ownership and operation. The operator of offshore transmission network assets has been designated as National Grid Electricity Transmission, as an extension of its role as the GB onshore system operator. It is currently proposed that a competitive tender process will take place for the ownership of the offshore transmission assets associated with any particular project. Therefore, the number of transmission owners (currently 3 onshore) could increase considerably in Great Britain.

47. This analysis has assumed that all the codes, including GB SQSS, Grid Code, STC, etc. will be accepted, bar minor changes, as written. The offshore section of the GB SQSS is of particular relevance, as it is this document that will dictate the minimum number of circuits and onshore terminus equipment required at the connection sites investigated. This is discussed further in Appendix 1, Building Blocks of Electricity Transmission.

48. The work undertaken and conclusions reached as part of this analysis are mainly concerned with the impact on the onshore transmission system, as opposed to that on the offshore transmission system. The extent of the offshore transmission system, from the *Offshore Grid Entry Point* to the *Onshore Interface Point,* is illustrated below, in Figure 8. It is clear that a certain portion of the offshore transmission network is in fact located onshore.

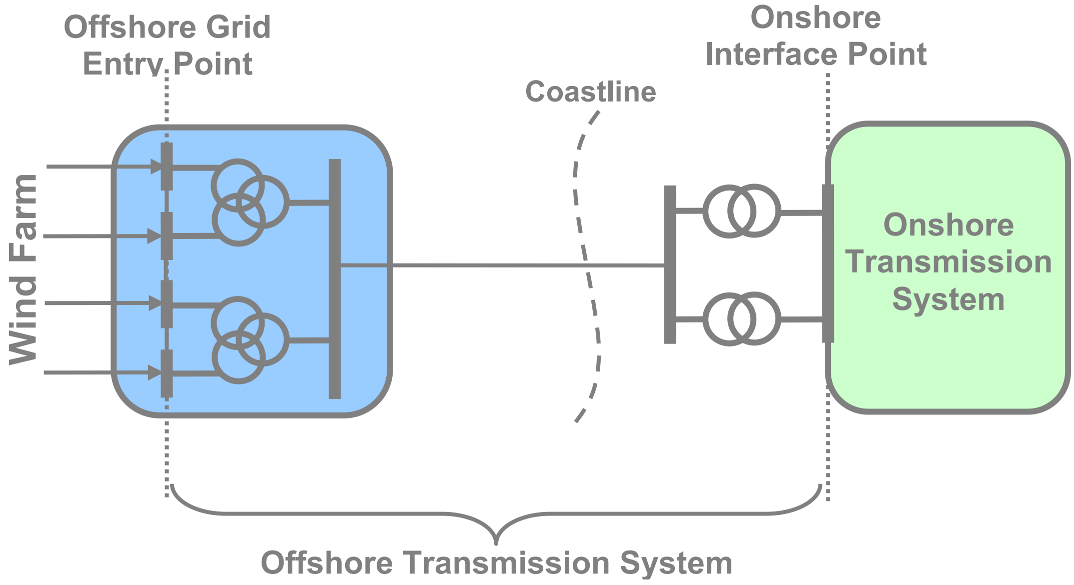


Figure 8 – Extent of an Offshore Transmission System

49. The use of a standard set of offshore network designs were assumed when assessing the impact on the onshore transmission system at the onshore interface point (i.e. at the substation where the offshore system connects, as explained in more detail in Appendix 1). These were based on the current proposals for the offshore section of the GB SQSS and are dependent on project size and distance from the shore.

50. The standard offshore network designs considered assume that offshore zones will be developed in an optimum, coordinated manner. This assumption leads to a significant reduction in the amount of assets that would be required in comparison with incremental project-by-project offshore development. A reduction in the number of transformers located at the onshore interface point is one example of such a reduction. In addition, depending on the relative size of offshore wind projects to the modular sizes of the connection technologies utilised in providing a connection to the onshore transmission system, further reductions could be possible in the number of cables coming ashore and the number HVDC converter stations at the onshore interface point. This study has assumed that all connections are fully optimised

3. Results Summary – Impact of Connecting Offshore Wind Energy

51. The following sections present the reinforcement work required to the onshore transmission system for the potential offshore wind generation volumes and possible connection points identified in the *Scenarios* section, above. The potential impact of these reinforcements is expressed in terms of the relevant 'building blocks' of electricity transmission that are explained in depth in Appendix 1.

52. The final choice of onshore connection points and the overall optimum network design would be determined by finding an economic balance between the offshore and onshore reinforcement required, including the cost and environmental impact of both local (substation and circuits) and wider (Main Interconnected Transmission System (MITS)) onshore reinforcements against the generation background. The onshore transmission system refers to the entire network beyond the onshore interface point forming the boundary between the onshore and offshore transmission systems, as illustrated in Figure 8.

53. Onshore transmission owners have a statutory obligation, through Section 38 of the Electricity Act 1989, to take into account amenity considerations when carrying out work on their systems. This is described further in Appendix 2.

54. In order to identify and cost the onshore connections and transmission reinforcements, three approaches to the overall system design were considered:

- Extending the offshore cables inland to existing onshore transmission sites;
- Extending the onshore transmission system to new connection substations at the coast;
- Hybrids of the above approaches.

55. An examination of the potential volumes of wind generation within Regional Sea areas show that they fall into two broad categories:

Regional Seas with the potential for only a few offshore wind developments and relatively small overall capacities (2000 Megawatts[8] or less)

56. For these zones, typified by the Western Channel or Celtic Sea, reinforcements to the onshore transmission system with a significant impact were not required against the scenario, apart from extensions to existing substations or the establishment of new substations at the onshore interface point. The analysis of possible onshore connection points has attempted to optimise the costs and impact of cabling from a landing point to an existing substation, to a new substation on an existing transmission route, or to a new substation close to the coast, with the onshore transmission system extended to it. The savings in cable costs due to connecting to a new, rather than an existing, substation could outweigh the cost of a new substation in some instances. However, as explained in Appendix 1, the visual impact of a new substation would be greater.

Regional Seas with the potential for several offshore wind developments and larger capacities (greater than 2000 Megawatts)

57. For these areas – Irish Sea, or the Southern North Sea – the approach was similar to that used for the smaller zones but the larger power injections arising from full scale development meant that significant transmission network reinforcement would be necessary. The analysis of possible onshore connection points therefore included the costs and impact of reinforcing the 'wider' onshore transmission system (such as overhead lines) as well as the cost and impact of simply connecting the offshore wind to one or more onshore substations.

---
[8] 1000 Megawatts (MW) = 1 Gigawatt (GW)

58. The overall system changes required for full development of these larger zones are such that a wind farm by wind farm analysis is unhelpful. The environmental impact and costs are driven by the totality of the installed wind generation, and cannot be itemised to individual wind farms. Put another way, each individual wind farm might require little or no significant 'wider' system reinforcement, but in combination they may. Impacts on the onshore transmission system are therefore presented for complete areas with consideration given to the installed Megawatt (MW) level at which a particular reinforcement is required against the assumed background conditions.

59. Specifically the reinforcement requirements and impacts are split into two sections. The local connection work for offshore wind capacities of 500MW, 1000MW and 2000MW (excluding 2000MW in Scotland) at the possible onshore connection points (i.e. for substation work) and the impact of connecting a total of 5, 10, 15, 20 and 25GW to the wider system (e.g. overhead lines) based on the assumptions described in the *Scenarios* section, above.

60. The connections required for new overhead line routes are detailed in the relevant geographical area below together with a high-level description of the line routeing issues for them. These routes have been subject to high-level desk-top examination only, using a range of data from the "MAGIC" environmental website[9] and the National Grid, Geographic Information System to identify areas of constraint. The routes shown are indicative only, to demonstrate the areas through which the identification of appropriate corridors may be required, following detailed investigation. No detailed environmental impact assessment has been undertaken at this stage.

[9] www.magic.gov.uk

Regional Sea 1 – Northern North Sea

Characteristics of Transmission network:

61. The electricity transmission system in Scotland, illustrated in Figure 9, is characterised by interconnected 132kV and 275kV circuits and a large proportion of radial networks in the north (Scottish Hydro Electric Transmission Limited, SHETL, area) and a greater amount of 275kV and 400kV circuits in the south (Scottish Power Transmission, SPT, area) representing a stronger network. This is shown in Figure 9, below. Generation in both these areas is increasing at a significant rate due to the high volume of new onshore wind generation seeking connection as mentioned above. Consequently, power flows on the network are also increasing rapidly up to the maximum capacity of the network.

62. Several reinforcements are already planned to address this issue. The outcome of the planning process is awaited in respect of the proposed rebuild of an existing 132kV overhead line between Beauly and Deny that will alleviate these constraints to a certain extent and eventually allow for the connection of more renewable generation in this area. Further reinforcements are also planned through the north and south of Scotland as well as down into England to allow the electricity generated to reach the centres of greatest demand.

63. However, these reinforcements alone are not sufficient to accommodate the volumes of renewable generation expected to materialise out to 2020 and beyond.

Figure 9 – Onshore Transmission System in Scotland

Transmission Reinforcements Required:

64. As previously mentioned, this study will not look to pre-empt the ongoing work through the ENSG, being undertaken by onshore transmission owners. Therefore, for offshore wind generation connections with the Regional Sea 1 – Northern North Sea area, only the 'local connection work' have been considered.

Moray Firth

65. Potential connection points investigated are:

Blackhillock: An existing 275 kV switching station, about 20 km inland from the Banffshire coast;

Lintmill: A new site on the route of an existing 132 kV circuit, about 3 km from a potential cable-landing point in Cullen Bay;

Peterhead: An existing power station and 275 kV substation on the east coast.

Figure 10 – Moray Firth

66. For the purposes of this study, the location of the offshore wind developments in this region were assumed to be located within a distance from the shore suitable for the use of AC, rather than HVDC, connection technology (as detailed in Appendix 1). The exception to this is a connection to Peterhead, where the use of HVDC technology was considered likely to be more economic. This assumption does not preclude the use of HVDC technology for these connections. The choice of connection technology would be subject to the actual location of offshore wind projects and an economic assessment at the time of connection application.

Site-by-Site 'Local' Substation Reinforcement:

Table 8: Blackhillock Local Connection Work		
Existing Configuration	275 kV AIS Outdoor Double Busbar Switching Station, planned for development as 400/275 kV substation	
Local Environment[10]	No environmental designations	
Onshore Transmission Works & Issues	Extend proposed 400 kV busbars and construct new 132 kV busbars at substation, with additional 400/132 kV transformers as required (see below). Obtain permissions and consents.	
Offshore Transmission Works & Issues	Location of offshore transmission equipment (cable terminals and reactive compensation). Obtain land, planning consent, and interface with onshore transmission owner.	
Approximate Length of Cable Route from Coast	17 – 20km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1.0 GW
	4-bay extension of 400 kV substation, 4 x 400/132 kV transformers, 132 kV assets to connect 3 x 132 kV cables.	6-bay extension of 400 kV substation, 6 x 400/132 kV transformers, 132 kV assets to connect 6 x 132 kV cables.
Indicative Onshore Transmission Costs	0.5 GW	1.0 GW
	~ £23m*	~ £34m*
Estimated Timescales for 'Local' Onshore Transmission Work	2 to 3 years for substation extension	

*Costs for SHETL substation work have been calculated to include some 132kV assets that have not been included in the costing for SPT and National Grid work as per Figure 8, above. The exact location of the interface between offshore and onshore networks will be dependent on connection designs used.

---

[10] Source: http://www.magic.gov.uk

Table 9: Lintmill Local Connection Work		
Existing Configuration	No existing substation	
Local Environment[11]	Coastal area west of Portknockie is National Nature Reserve (NNR) designated. Coast area to the east of Lintmill has Site of Special Scientific Interest (SSSI) designation.	
Onshore Transmission Works & Issues	Establish new 400/132kV substation near Lintmill, close to the Keith – Macduff 132kV circuit. Interconnect with existing 132kV/33kV circuit to Macduff. Dismantle existing 132kV circuit from Lintmill to Keith Construct 400kV double circuit tower line from Lintmill to Blackhillock (~19km). Extend proposed Blackhillock 400kV by 2 bays. Obtain land and planning consents.	
Offshore Transmission Works & Issues	Location of offshore transmission equipment (cable terminals and reactive compensation) Obtain land, planning consent, and interface with onshore transmission owner	
Approximate Length of Cable Route from Coast	3km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1 GW
	none	Incremental impact is minimal. Only one additional substation bay required
Indicative Onshore Transmission Costs	0.5 GW	1 GW
	~£72m*	~ £83m*
Estimated Timescales for 'Local' Onshore Transmission Work	6 to 7 years based on 4 years OHL planning consent and 2 to 3 years construction	

*Costs for SHETL substation work have been calculated to include some 132kV assets that have not been included in the costing for SPT and National Grid work as per Figure 8, above. The exact location of the interface between offshore and onshore networks will be dependent on connection designs used.

[11] Source: http://www.magic.gov.uk

Table 10: Peterhead Local Connection Work		
Existing Configuration	275 kV Ring-bus	
Local Environment[12]	Situated within coastal farmland region. Coastal Special Protection Area (SPA) 3km east of existing substation. More detailed environmental analysis available through 'Proposed Shetland HVDC Connection' consultation document dated March 2008[13]	
Onshore Transmission Works & Issues	Extend any future 275 kV substation at Peterhead associated with a potential east coast HVDC interconnection to include two additional bays. Conditional on any future east coast HVDC interconnection as outlined in assumptions.	
Offshore Transmission Works & Issues	Location of offshore TO equipment (cable terminals and HVDC converters) Obtain land, planning consent, and interface with onshore TO	
Approximate Length of Cable Route from Coast	3km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1 GW
	n/a	Works as above
Indicative Onshore Transmission Costs	0.5 GW	1 GW
	n/a	~ £3m
Estimated Timescales for 'Local' Onshore Transmission Work	1 to 2 years after completion of HVDC link	

[12] Source: http://www.magic.gov.uk
[13] http://www.scottish-southern.co.uk/SSEInternet/uploadedFiles/Media_Centre/Project_News/Shetland/Documents_and_maps/ShetlandConsultationReport.pdf (Published by SHETL in March 2008)

Firth of Forth (Connection to SHETL Network)

67. Any future offshore wind generation in the Firth of Forth is assumed to materialise roughly equidistant from the coasts of Angus and East Lothian. Therefore, connections to the SHETL network at Arbroath or Tealing, and alternatively to the SPT network at Cockenzie, Torness or Branxton have been investigated.

Figure 11 – Firth of Forth

Table 11: Arbroath Local Connection Work		
Existing Configuration	No existing substation	
Local Environment[14]	Some coastal SSSI in the vicinity of Arbroath. No further local environmental designations.	
Onshore Transmission Works & Issues	Establish new 275/132 kV substation at Arbroath. Interconnect with existing 132 kV circuit to Brechin and Arbroath 33 kV. Construct 275 kV double circuit tower line from Arbroath to Tealing (~24km). Extend Tealing 275 kV substation by 2 bays. Identify viable substation site at/near Arbroath; obtain OHL and substation consents.	
Offshore Transmission Works & Issues	Location of offshore transmission equipment (cable terminals and reactive compensation) Obtain land, planning consent, and interface with onshore transmission.	
Approximate Length of Cable Route from Coast	3km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1 GW
	none	For 1000 MW, wider system works may be needed in 275 kV system
Indicative Onshore Transmission Costs	0.5 GW	1 GW
	~£80m*	~ £90m*
Estimated Timescales for 'Local' Onshore Transmission Work	6 to 7 years; based on 4 OHL planning consent and 2 to 3 years construction	

*Costs for SHETL substation work have been calculated to include some 132kV assets that have not been included in the costing for SPT and National Grid work as per Figure 8, above. The exact location of the interface between offshore and onshore networks will be dependent on connection designs used.

[14] Source: http://www.magic.gov.uk

Table 12: Tealing Local Connection Work		
Existing Configuration	275 kV substation	
Local Environment[15]	No local environmental designations.	
Onshore Transmission Works & Issues	Extend Tealing 275 kV substation. Obtain land and planning consents.	
Offshore Transmission Works & Issues	Establish second, independent 132kV substation at Tealing including space for location of offshore transmission equipment (cable terminals and reactive compensation) Obtain land, planning consent, and interface with onshore transmission	
Approximate Length of Cable Route from Coast	23km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1 GW
	Established substation with potential for expansion.	Increased 132 kV substation size to accommodate more transformers and reactive compensation. For 1000 MW, wider system works may be needed in 275 kV system
Indicative Onshore Transmission Costs	0.5 GW	1 GW
	~£20m*	~ £28m*
Estimated Timescales for 'Local' Onshore Transmission Work	2 to 3 years substation construction	

*Costs for SHETL substation work have been calculated to include some 132kV assets that have not been included in the costing for SPT and National Grid work as per Figure 8, above. The exact location of the interface between offshore and onshore networks will be dependent on connection designs used.

[15] Source: http://www.magic.gov.uk

Table 13: Cockenzie Local Connection Work		
Existing Configuration	Indoor 275 kV AIS Breaker and a Half	
Local Environment[16]	Site of existing coal fired power station. Firth of Forth coastal regions have Important Bird Area designation. ~1km from RAMSAR, SSI and SPA region to the east	
Onshore Transmission Works & Issues	Re-use of redundant circuit bays in 275 kV substation as generation circuits may be possible	
Offshore Transmission Works & Issues	Establish site for transformers, switchgear, cable terminations and reactive compensation. This may be possible adjacent to the existing substation. Obtain land and planning consent, interface with onshore transmission	
Approximate Length of Cable Route from Coast	< 0.5km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1 GW
	Land and consent for offshore transmission works	
Indicative Onshore Transmission Costs	0.5 GW	1 GW
	minimal	minimal
Estimated Timescales for 'Local' Onshore Transmission Work	minimal	

16 Source: http://www.magic.gov.uk

Table 14: Torness Local Connection Work		
Existing Configuration	Indoor 400 kV AIS Double Busbar	
Local Environment[17]	Site of existing nuclear power station. Coastal SSSI region directly north west of existing substation.	
Onshore Transmission Works & Issues	No scope for expanding 400 kV substation. Possible to achieve maximum of 400 MW capacity by replacing two 400/132 kV transformers with larger units. Installation of second pair of 400 kV cables in Torness – Eccles circuits required Extension of 132 kV substation to accommodate switchgear for offshore cable circuits may be possible	
Offshore Transmission Works & Issues	Obtain land for cable terminations and reactive compensation at or adjacent to existing 132 kV substation. Obtain land and planning consent, interface with onshore transmission	
Approximate Length of Cable Route from Coast	< 0.5km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1 GW
	Connection limited to 400 MW by transformer ratings and 400 kV substation	Not feasible due to 400 kV substation restrictions
Indicative Onshore Transmission Costs	0.5 GW	1 GW
	~£15m	n/a
Estimated Timescales for 'Local' Onshore Transmission Work	4 to 5 years; based on transformer lead time of 4 years	

[17] Source: http://www.magic.gov.uk

Table 15: Branxton Local Connection Work		
Existing Configuration	400 kV Cable Sealing-End Compound	
Local Environment[18]	Proposed site located on farmland. No local environmental designations	
Onshore Transmission Works & Issues	Establish new 6 or 7 bay 400 kV double-busbar substation on site of existing sealing-end compound. Obtain land, planning consent, and interface with onshore transmission	
Offshore Transmission Works & Issues	Establish site for transformer(s), switchgear, cable terminations and reactive compensation adjacent to new SPT Branxton substation	
Approximate Length of Cable Route from Coast	~20km	
Impacts for Varying Levels of Installed Capacity	0.5 GW	1 GW
	6-bay 400 kV substation needed	7-bay 400 kV substation needed, plus more land for offshore transmission works
Indicative Onshore Transmission Costs	0.5 GW	1 GW
	~£30m	~£30m+
Estimated Timescales for 'Local' Onshore Transmission Work	6 to 7 years	

[18] Source: http://www.magic.gov.uk

Characteristics of Transmission network:

68. The nearest feasible landing points for power from Dogger Bank and the sea to the North-East of the Wash are the South Durham coast, the Yorkshire coast to the south of Bridlington, and the Lincolnshire coast. Onshore transmission development in the North Yorkshire Moors National Park, in the Yorkshire Wolds or in the coastal area between Scarborough and Bridlington is likely to be particularly contentious, so is not considered in this analysis.

69. For reasons discussed below, the preferred areas for connection are the coasts of Yorkshire and/or Lincolnshire.

70. The main 400kV interconnected transmission system runs through Yorkshire and Lincolnshire as depicted in Figure 12, below.

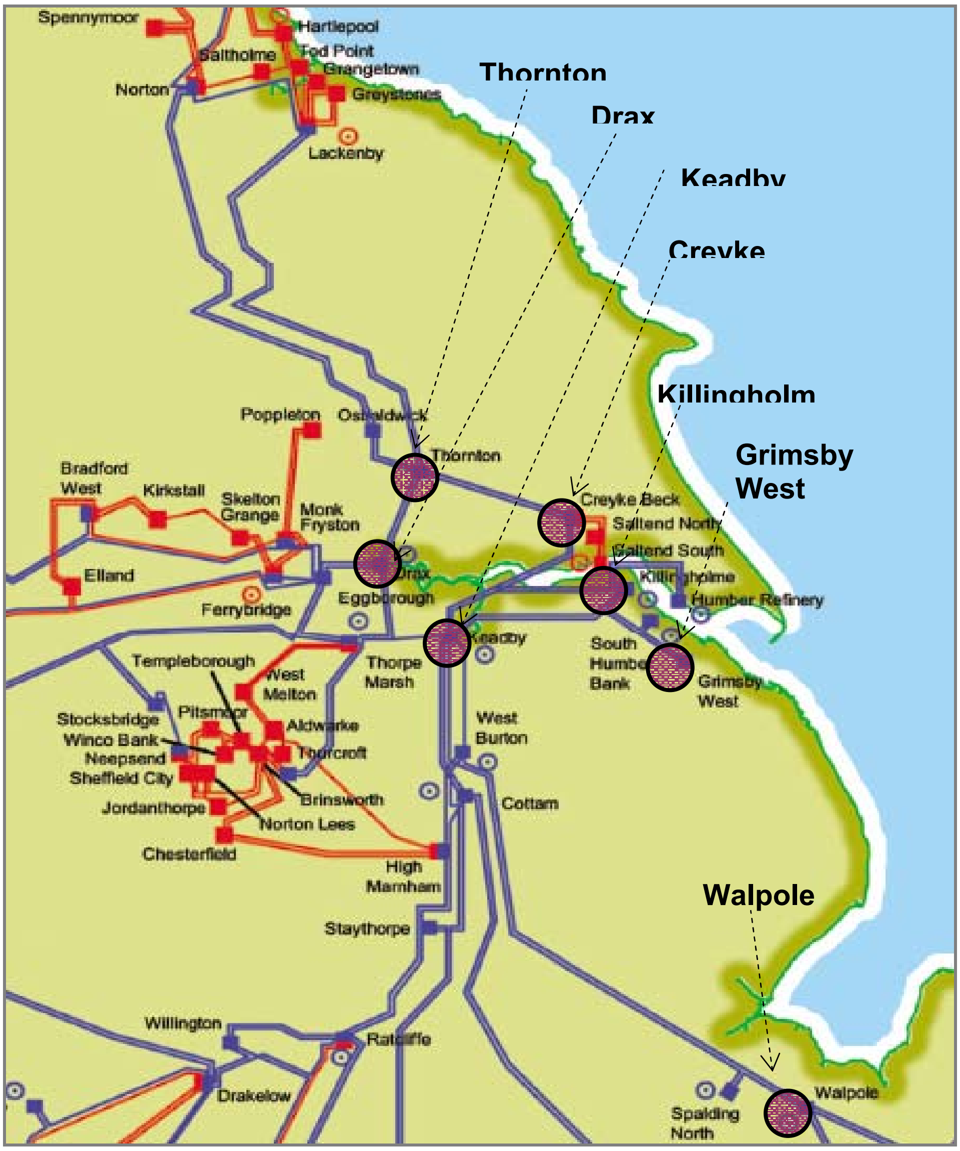


Figure 12 – Onshore Transmission System Yorkshire and Lincolnshire

71. The layout and function of the 400kV onshore network in this area can best be considered by describing it in three sections. This is done below.

72. A “central spine”, running from Creyke Beck substation near Hull, south to Keadby near Scunthorpe and then following the Trent south to the power stations at West Burton, Cottam and Ratcliffe. This section of network carries north-south transfers from Scotland and N.E. England together with output from power stations on the Humber, gathers the output of power stations on the Trent and links to the circuits supplying the London and West Midlands conurbations.

73. An eastern loop which consists of two 400 kV lines running from Keadby towards Killingholme, with one line continuing towards Grimsby. These lines gather the outputs of power stations on the south side of the Humber and feed it into the main system at Keadby.

74. A western section that interconnects the existing large coal-fired power stations at Drax, Eggborough and Ferrybridge. This part of the network also supplies the demand centres of West Yorkshire and the Sheffield area, and interconnects with the 400 kV system in Lancashire and Cheshire.

75. Two 400 kV lines run from the north of the area towards Teesside and the North-East, while four lines run south to the Midlands, East Anglia and the South East. Given the disposition of generating plant in the GB system, the predominant pattern of power flows is from North to South and consequently this part of the network can often be heavily stressed.

76. Against both the contracted and non-contractual backgrounds, transfers from the North are such that the North-East to Yorkshire lines would require uprating (new conductors) to carry the power from onshore and Rounds 1 & 2 offshore wind, together with conventional generation in Scotland and the North East. Any further generation in the connected in the North East, including further offshore wind generation, would trigger a requirement for one or more additional lines to Yorkshire. Delays and difficulties in gaining consents for these circuits can be expected. Given the interaction between the factors outlined above and the likelihood of such an overhead line being required, the North East was considered an unattractive option for connecting further offshore wind developments and is not considered further in this analysis.

Offshore Wind Connection Options and Issues

77. The offshore wind generation locations in the northern sector of Regional Sea 2, for those developments beyond the 8GW already planned (hereafter referred to as Round 3), are located so far offshore that only HVDC cables can be considered as practical and economic connection options given current or foreseeable technology. These will be terminated in converter stations, which will require substantial buildings at or adjacent to the onshore substations as explained in Appendix 1.

78. One option for connecting offshore wind generation is to bring cables ashore to coastal substations (existing or newly-built) and reinforce the 400 kV network as necessary; another is to extend the HVDC cables further inland to existing substations. The estimated costs of the HVDC cables are such that either solution may be economic, depending on the local circumstances. The arrangements described below are actually hybrids of the two approaches.

Transmission Reinforcements Required:

Wider System Reinforcement:

79. As described, the most economic and practical connection points for Dogger Bank wind farms are in Yorkshire and North Lincolnshire, in a central part of the 400 kV onshore transmission system (both Options A and B refer, below). Reinforcement requirements in this area, and over a wider area of the system will be driven by the Round 3 wind generation but also by the output of existing and potential conventional generation in Yorkshire and Lincolnshire, power transfers from the North East of England, due to conventional generation developments, and power transfers from Scotland due in part to onshore and offshore wind generation. In these circumstances it is not possible to show a simple and definite relationship between the quantity of Round 3 wind and the reinforcements required. The results presented below are indicative of what may ultimately be needed but the timing of reinforcements would depend on the order and location of generation developments over a wide area. Depending on those generation developments (particularly Scottish onshore wind and conventional plant in the North-East and Humberside) some reinforcement may be required irrespective of the Round 3 wind.

80. In exploring the three approaches to system development outlined in paragraph 54, above, two options for reinforcing the onshore transmission system were identified. These are outlined in Table 16 and Table 17 and discussed further below.

Dogger Bank and Northern Wash: Wind Connection Options and System Reinforcement Requirements for Assumed Total of 11GW Round 3 Offshore Wind Generation

Table 16: Option A - Inland and Coastal Connection Sites

Total Offshore Generation Capacity (GW)	Year (Notional)	Connection Configuration	Area Total Generation Capacity (GW)	Major Reinforcements Requirements
25	2020/21	Inland and Coastal Onshore Connection Sites	11GW	Re-conductor Drax-Eggborough overhead line. Uprate Brinsworth – Chesterfield 275 kV overhead line to 400 kV. Build a new 400 kV substation at Chesterfield and a new 400kV overhead line from Chesterfield to Willington substations. New 400 kV overhead line from Creyke Beck to Drax substation or from Drax to Keadby substation.

Table 17: Option B - Mostly Coastal Connection Sites				
Total Offshore Generation Capacity (GW)	Year (Notional)	Connection Configuration	Area Total Generation Capacity (GW)	Major Reinforcements Requirements
25	2020/21	Mostly Coastal Connection Sites	11GW	New 400kV overhead line from Grimsby West to Bicker Fen or Walpole substations (Lincolnshire coast) New 400kV overhead line from Bicker Fen or Walpole to a new substation near Peterborough on the existing Cottam to Eaton Socon overhead line route. New 400 kV overhead line from Creyke Beck to Drax substation (or new 400 kV overhead line from Killingholme to West Burton substation).

Potential Overhead Line Requirements

East Riding Yorkshire

81. The introduction of offshore wind generation connections to this region, on the Western boundary of Hull, could also require further reinforcement of the 400kV system to support power flows into the West Yorkshire / Midlands areas. This would involve a new, approximately 40km long, 400kV overhead line between the existing 400kV substations at Drax and Creyke Beck. This is indicated in orange on Figure 13, below. The need for this line is dependant on the total generation capacity connected via here and would have to be balanced against alternative works elsewhere if some of the capacity was connected further south. One alternative is described in the Lincolnshire section, below.

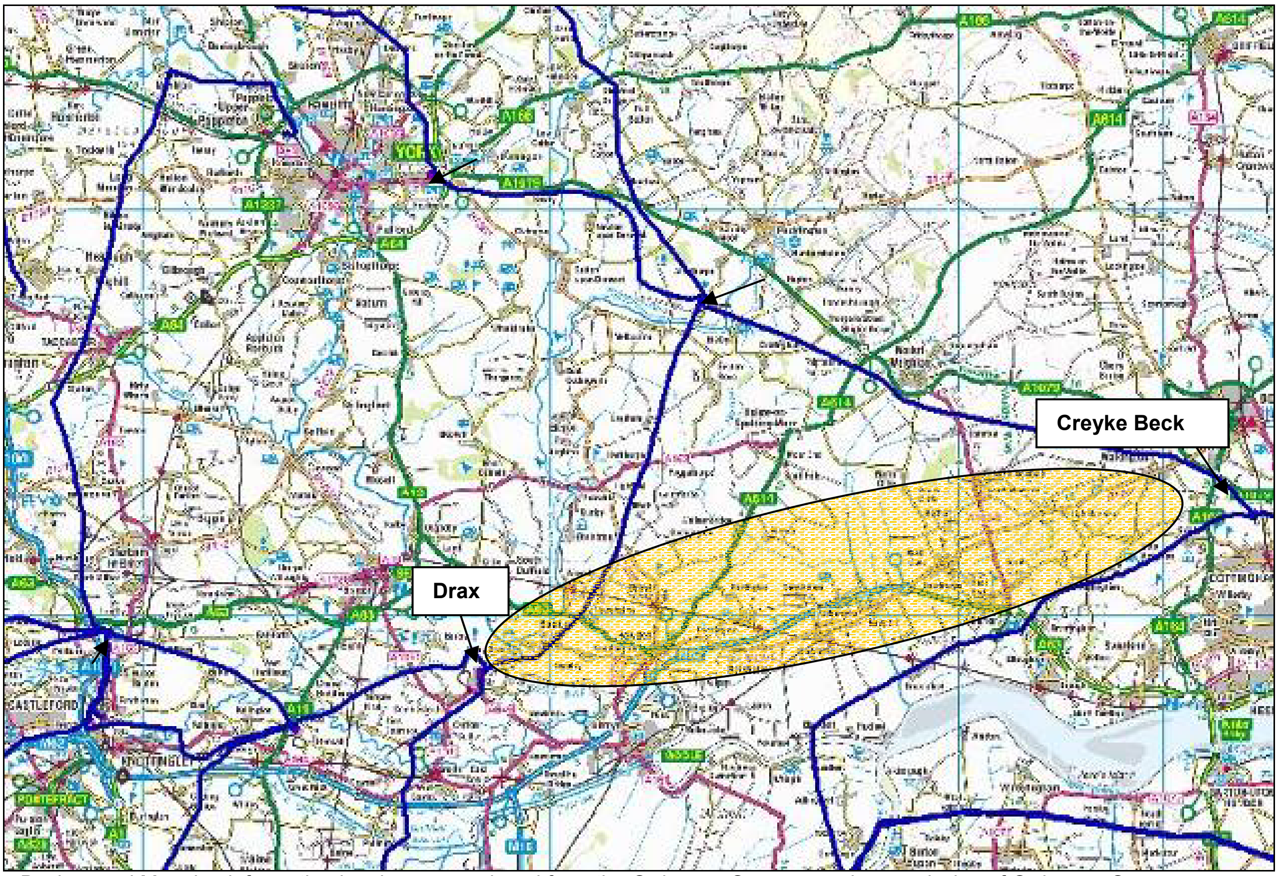


Figure 13 – Potential New Overhead Line Requirements in Yorkshire

<u>Derbyshire</u>

82. Depending on the overall design solutions and connection points adopted for the Dogger Bank offshore wind, the possibility exists of a need to create a new 400kV overhead line between Chesterfield and the existing substation at Willington, south of Derby. A new 400kV substation would also be required at Chesterfield, adjacent to the existing 275kV substation, including modifications to the existing overhead lines in this area. This new overhead line is associated with ‘Option A’, presented in Table 16 and presented in blue on Figure 14.

83. The route between these sites is constrained by the World Heritage site, of the Derwent Valley, shown in red. It is not the policy of any onshore transmission owner to route overhead lines through World Heritage sites (as explained in Appendix 2), and hence this leads to the initial belief that an alternative route through the green belt to the east of Derby may be preferable.

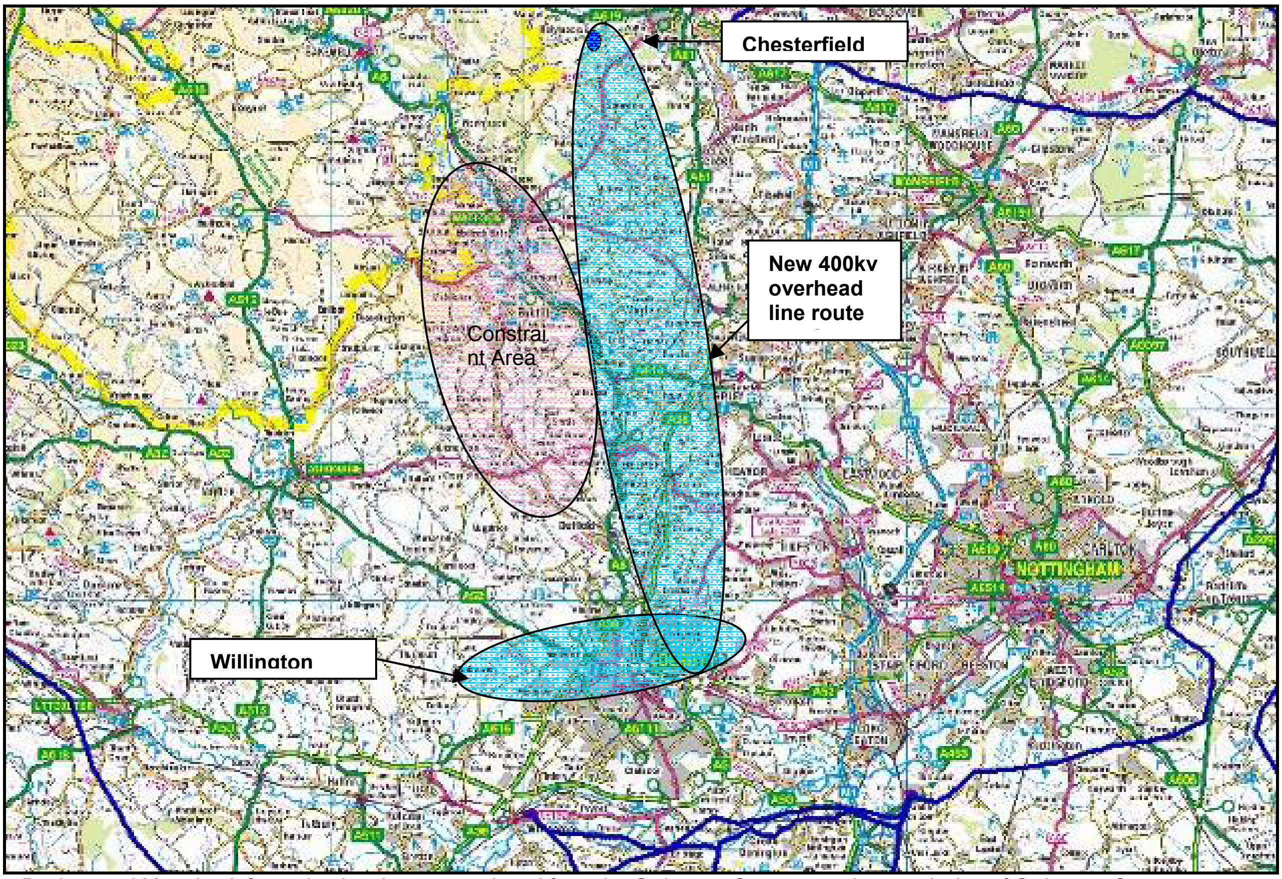


Figure 14 – Potential New Overhead Line Requirements in Derbyshire

Lincolnshire

84. Studies have identified that the required connections to offshore wind generation projects located in the North Sea area, are preferable to the south of the Humber from a system perspective. This requires expansion of the main interconnected onshore transmission system to increase North-South capacity from this region. There is also the possibility of facilitating the connection of the offshore wind generation through establishing new substations along the east coast, reducing the extent of offshore connections required. This tends to support a new 400kV route closer to the coast, presented as ‘Option B’ in Table 17.

85. Connection points have been investigated at existing sites along the Humber estuary. The shipping traffic in the Humber may inhibit the ability of the offshore transmission owners to install submarine cables to sites in this area. Final designs will require the identification of locations where the routeing and landing of the offshore cables can occur, as well as the relative locations of existing onshore substations.

86. A new 400kV route from the existing Grimsby West 400kV substation site running for approximately 80km to connect into Bicker Fen (or Walpole) 400kV substations is an option proposed (i.e. Option B). From this termination point further East-West capacity is required necessitating an additional overhead line to connect to the existing Eaton Socon to Cottam overhead line route, to the west.

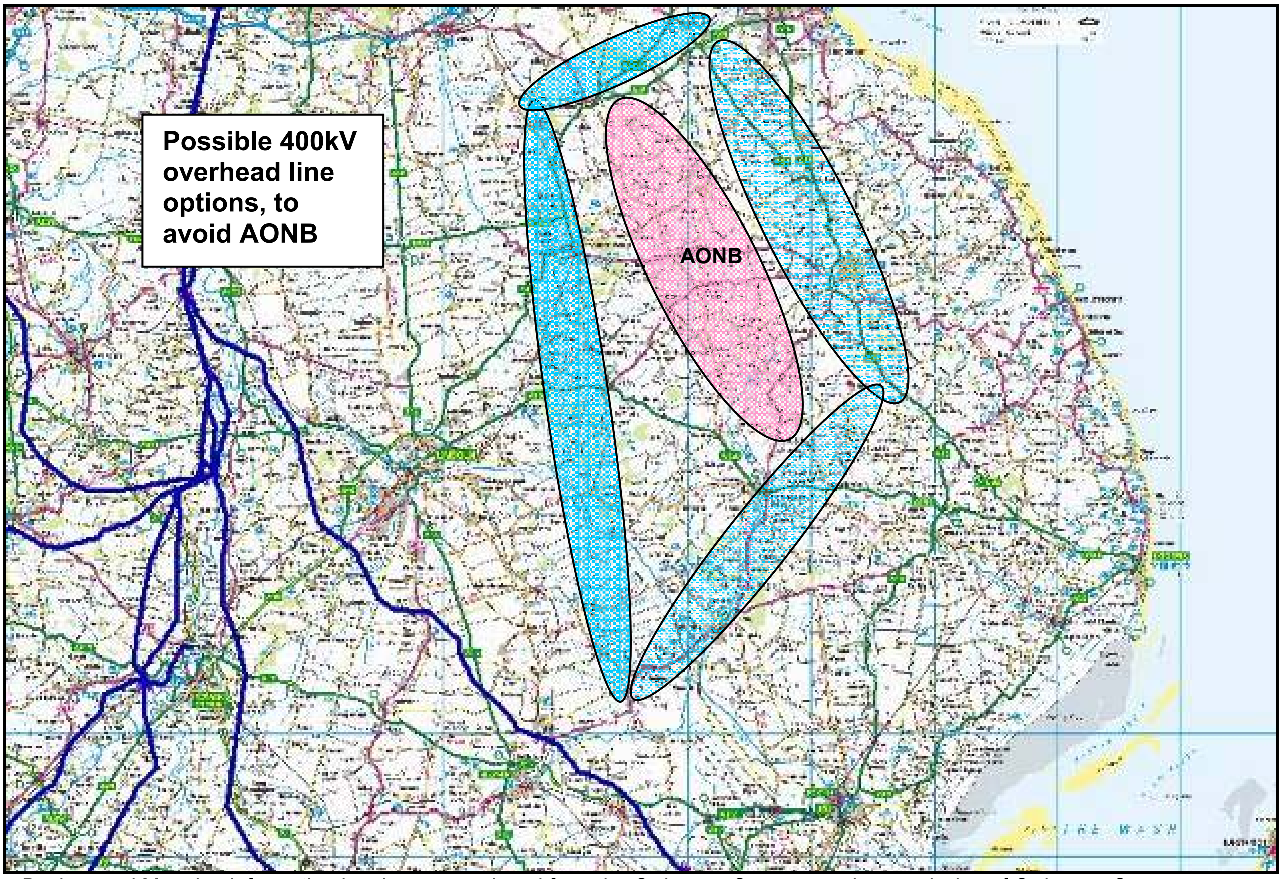


Figure 15 – Potential New Overhead Line Requirements in Lincolnshire

87. The main environmental constraint is the Lincolnshire designated "Area of Outstanding Natural Beauty" (AONB). The options for these lines are indicated on Figure 15 in blue. The AONB is indicated in red.

88. To accommodate the extent of the North Sea area capacity a new substation connecting to two existing 400kV lines in the south Humber area is proposed. Depending on the application of licence standards (as explained in Appendix 3) and how wind farm capacity is to be considered this could require a further 400kV overhead line to be established in this area to an existing onshore transmission substation at West Burton. This additional line, indicated in orange on Figure 16 is dependant upon the quantity of generation connected in this area, similar to the East Yorkshire connections described above.

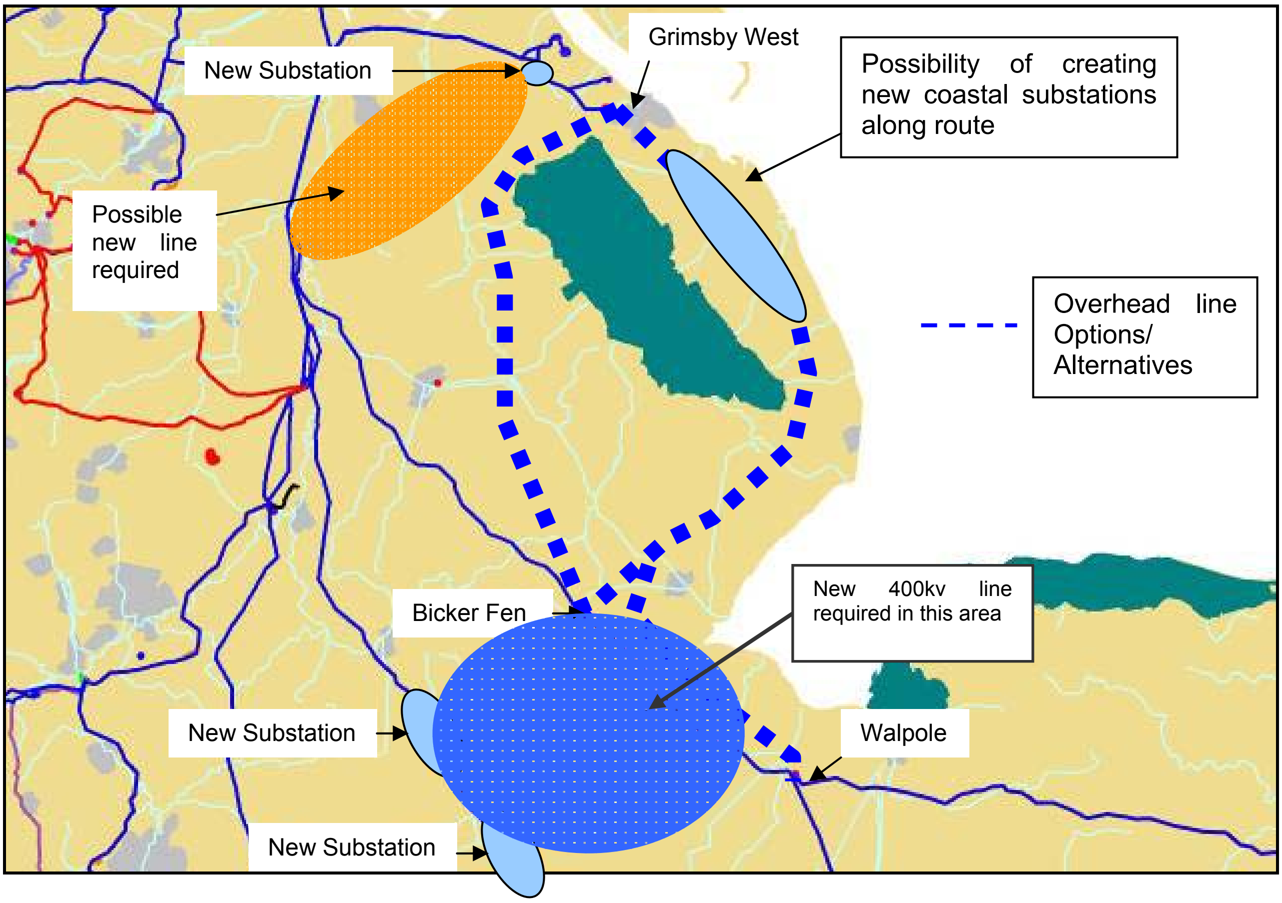


Figure 16 – Potential New Overhead Line Requirements in Lincolnshire

Site-by-Site 'Local' Substation Reinforcement:

Table 18: Thornton Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Open agricultural, rural area east of York. No local environmental designations that affect site extension.
Onshore Transmission Works & Issues	Need to extend substation for connection of the offshore/onshore transmission interface equipment as well as the potential for new overhead line connections (as described above) require additional land and planning permission.
Offshore Transmission Works & Issues	Land and planning permission for locating offshore transmission installation is required in the vicinity of the existing substation. Suitable access route for transformers, as described in Appendix 1, required.
Approximate Length of Cable Route from Coast	~ 50km
Impacts for Varying Levels of Installed Capacity	An HVDC connection at this site would require 2 additional 400kV bays for each converter installation (with potential for optimisation with multiple connections as described in Appendix 1). The maximum capacity of a converter is currently expected to be 1.1GW.
Indicative Onshore Transmission Costs	£30 m
Estimated Timescales for 'Local' Onshore Transmission Work	5 to 6 years for substation extension

Table 19: Drax Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Site of an existing coal fired power station with adjoining open fields. Location is dominated by scale of existing Drax power station. No local environmental designations that affect site development.
Onshore Transmission Works & Issues	Modification and extension of existing substation configuration for connection of offshore transmission network. Sufficient space for all local onshore transmission system work to be contained within existing substation area.
Offshore Transmission Works & Issues	No space available in existing substation for offshore transmission equipment. Land purchase and planning permission required for offshore substation. Congested existing cable routes into substation restrict access to circuit bays (as described in Appendix 1). The HVDC converters required would need to be constructed remotely from the substation, with the nearest area being on the opposite side of a public highway adjacent to the site.
Approximate Length of Cable Route from Coast	~70km
Impacts for Varying Levels of Installed Capacity	An HVDC connection at this site would require 2 additional 400kV bays for each converter installation (with potential for optimisation with multiple connections as described in Appendix 1). The maximum capacity of a converter is currently expected to be 1.1GW.
Indicative Onshore Transmission Costs	£20m
Estimated Timescales for 'Local' Onshore Transmission Work	4 years

Table 20: Creyke Beck Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Within agricultural area on outskirts of Hull. No local environmental designations. Property to the north of the substation would preclude extension in this direction. Changes to local roads/ access to third party properties needed to accommodate site expansion.
Onshore Transmission Works & Issues	To accommodate the works extension of the substation will be required. This will require an existing overhead line to be diverted to permit this. Additional land and planning consent will be required. An additional 400kV overhead line circuit may also be required depending upon the capacity connected at this location. The extent of site extension will vary depending upon this.
Offshore Transmission Works & Issues	The location of the HVDC converters (as described in Appendix 1) requires land purchase and planning consent. These will dominate the local environment from a visual amenity perspective.
Approximate Length of Cable Route from Coast	~25km
Impacts for Varying Levels of Installed Capacity	An HVDC connection at this site would require 2 additional 400kV bays for each converter installation (with potential for optimisation with multiple connections as described in Appendix 1). The maximum capacity of a converter is currently expected to be 1.1GW.
Indicative Onshore Transmission Costs	£15m
Estimated Timescales for 'Local' Onshore Transmission Work	6 to 8 years

Table 21: Grimsby West Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Part Mesh
Local Environment	On the fringe of the Urban area of Grimsby. Existing substation located in area of farmland, with tree screening between site and local housing area. No local environmental designations.
Onshore Transmission Works & Issues	Installation of new 400kV double busbar substation (as explained in Appendix 1) within existing onshore transmission owner land ownership boundary Modification of overhead line entries and potential provision for connection of a new 400kV overhead line to create southern route for power export (as explained above). Permissions and consents required to undertake work.
Offshore Transmission Works & Issues	Locating of onshore/offshore transmission interface equipment may be possible within existing onshore transmission owner land ownership boundary. Planning consent and interface with onshore transmission owner
Approximate Length of Cable Route from Coast	~3km
Impacts for Varying Levels of Installed Capacity	An HVDC connection at this site would require 2 additional 400kV bays for each converter installation (with potential for optimisation with multiple connections as described in Appendix 1). The maximum capacity of a converter is currently expected to be 1.1GW.
Indicative Onshore Transmission Costs	£25m
Estimated Timescales for 'Local' Onshore Transmission Work	6 to 8 years

Table 22: Keadby Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Location of existing coal fired power station Brownfield site; No local environmental designations.
Onshore Transmission Works & Issues	Modification and extension of existing substation within existing substation fence line and onshore transmission owner land ownership boundary. Minimum of 2 circuit bay extensions required for interface.
Offshore Transmission Works & Issues	Identification of potential land area requirements and design of installations to fit into available areas may allow all onshore/offshore interface equipment to be located with the existing onshore transmission owner land ownership boundary.
Approximate Length of Cable Route from Coast	~5km (cabling up the Humber)
Impacts for Varying Levels of Installed Capacity	An HVDC connection at this site would require 2 additional 400kV bays for each converter installation (with potential for optimisation with multiple connections as described in Appendix 1). The maximum capacity of a converter is currently expected to be 1.1GW.
Indicative Onshore Transmission Costs	£10m
Estimated Timescales for 'Local' Onshore Transmission Work	4 – 5 years

Table 23: 'Near Killingholme' Local Connection Work	
Existing Configuration	No existing substation
Local Environment	Location near to existing coal fired power station and Industrial area. Agricultural area adjacent to existing installations. No local environmental designations.
Onshore Transmission Works & Issues	New indoor 400kV GIS double busbar to be developed (as detailed in Appendix 1) within an industrial area. Acquisition of land and necessary planning permissions required. Modifications of existing overhead line entries to new site required. Obtaining system access (i.e. outages; as explained in Appendix 4) for overhead line changes and re-configuration of the system is a potential constraint/risk to programme.
Offshore Transmission Works & Issues	Locating of onshore/offshore transmission interface equipment and connection to onshore transmission site. Land purchase and planning permission required.
Approximate Length of Cable Route from Coast	3km
Impacts for Varying Levels of Installed Capacity	New substation with two additional 400kV circuit bays required. The maximum capacity of a converter is currently expected to be 1.1GW. If more than 2 HVDC converters (i.e. more than 2.2GW) are connected, the proposed substation configuration may require alteration.
Indicative Onshore Transmission Costs	£40m
Estimated Timescales for 'Local' Onshore Transmission Work	7 years

Table 24: Walpole Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Rural location amongst farmland. No local environmental designations restricting development.
Onshore Transmission Works & Issues	Existing extension proposals for Round 2 offshore wind and gas generation projects at this site influence/constrain the ability to expand further without the potential need to establish a new substation Wider network issues to be resolved and balance of economic arrangement and environmental impacts to be considered in greater detail. Additional land and planning permission required for any extension. Possible third party works to divert existing distribution network assets required.
Offshore Transmission Works & Issues	Need for further additional land and planning permission. Significant offshore cable connection length from assumed location of offshore developments. Site unlikely to be suitable for economic connection of Round 3 offshore wind generation.
Approximate Length of Cable Route from Coast	~10km
Impacts for Varying Levels of Installed Capacity	Likelihood of need for additional 400kV substation due to volume of existing and contracted generation at this site.
Indicative Onshore Transmission Costs	£35m
Estimated Timescales for 'Local' Onshore Transmission Work	6 to 7 years

Characteristics of Transmission network:

89. The nearest landing points for Round 3 offshore wind generation, given the assumed offshore locations of the generation in this part of the regional sea, is in the East Anglia area.

90. The onshore 400kV transmission system in this part of the country is illustrated in Figure 17, below. It is characterised by a double circuit ring that links Walpole, Norwich, Bramford, Pelham and Burwell substations. This double circuit ring serves the demand centres of King's Lynn, Norwich, Ipswich, Bishop's Stortford and Cambridge respectively. Four circuits (approximately 43km route length) run towards the coast from Bramford substation to Sizewell, forming an overhead line radial spur. This spur provides a transmission corridor for the existing advanced gas-cooled reactor (AGR) nuclear generator located at Sizewell. The assumed generation and demand scenarios utilised for this study also includes the Round 2 offshore wind farm, Greater Gabbard, at Sizewell.

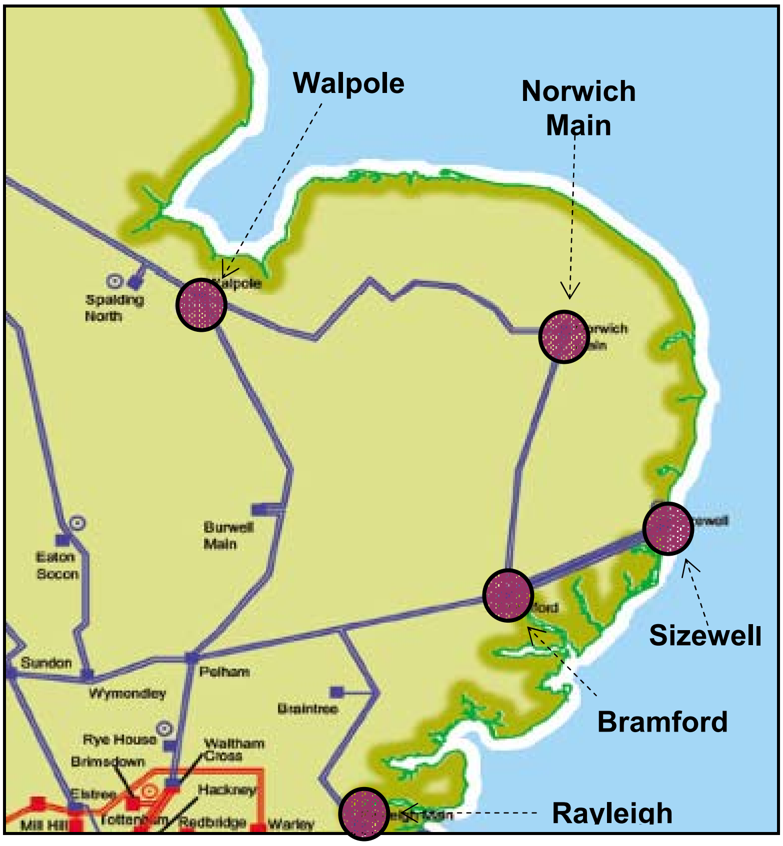


Figure 17 – Transmission System East Anglia

91. Two 400kV lines run north from Walpole towards Cottam and West Burton linking into the "central spine" of the transmission system described in paragraph 72. As such, this part of the transmission system carries power transfers from generation in the North East of England. (see Attachment 2 for full map of the onshore transmission system)

92. At the bottom of the East Anglia loop there is a circuit route between Pelham, Bramford and Rayleigh Main that is a corridor for generation from the power stations at Walpole, Norwich and Sizewell, carrying it further south towards Essex and Kent.

93. Pelham substation provides additional interconnection between the East Anglia region and other sections of the transmission system. Two 400kV lines runs west from Pelham to supply demand centres in west Hertfordshire and another two 400kV lines run south extending the transmission system to the outskirts of Greater London.

94. The generation background assumption utilised in the scenarios are such that the existing onshore transmission overhead lines would require upgrading (i.e. re-conductoring) to facilitate the transfers from conventional generation and Round 2 offshore wind generation assumed connected in this region. Therefore any Round 3 wind generation would trigger further reinforcement.

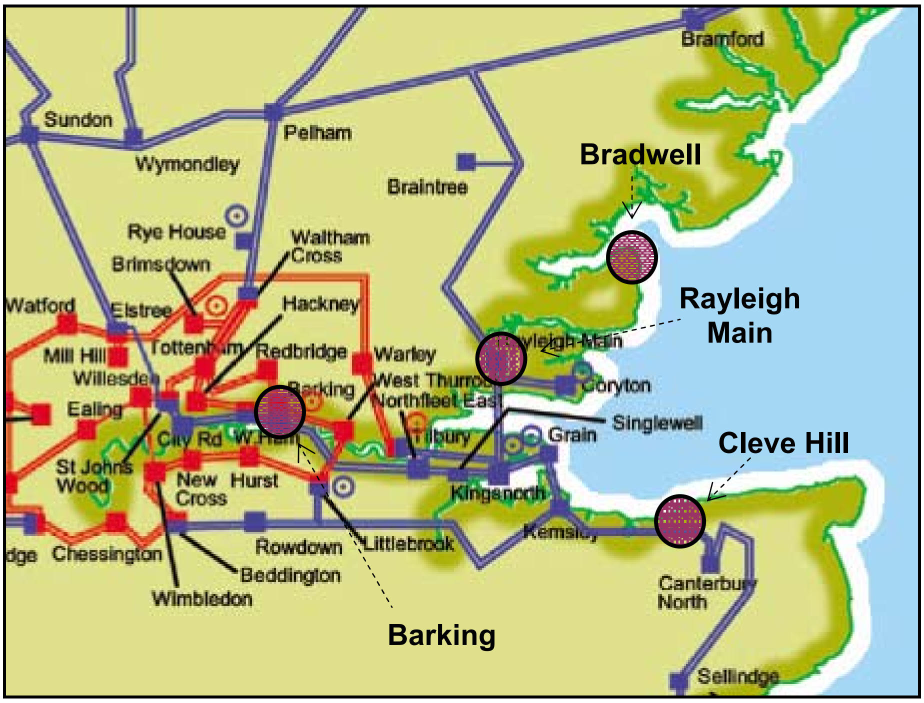


Figure 18 – Transmission System East London, Essex, Kent Anglia

95. Rayleigh Main substation lies outside the previously mentioned double circuit transmission ring in East Anglia (see Figure 17). It is located approximately 63km south of Bramford, north-east of Basildon. Two 400kV circuits run north from Rayleigh Main; one connects at Pelham and the other at Bramford. Similarly, two circuits run south towards the River Thames; one circuit to Coryton South substation the other to Tilbury. A 132kV double circuit route runs north-east from Rayleigh out towards the Essex coast and the river Blackwater to Bradwell substation. This circuit had provided the connection to the main transmission system for the Bradwell nuclear site until it began decommissioning in 2002.

Offshore Wind Connection Options and Generation Sensitivities

96. For the southern area of Regional Sea 2, it has been assumed that HVDC cables will be the most economic technology for the connection of offshore wind generation. The actual choice of technology used will be subject to economic evaluation at the time of submitting a connection application.

97. The option of connecting offshore wind generation to new coastal substations has not been investigated in detail for the southern North Sea area at this stage. Any new coastal substation would require additional overhead lines to connect it to the existing

onshore transmission system, which generally come with difficulties in gaining the necessary planning consents. In addition, extending the transmission system to the coast does not negate the requirement for further reinforcement out of the East Anglia region to the rest of the interconnected system for the total amount of offshore wind generation assumed to connect in this region. Therefore the connection options described below will focus on bringing HVDC cables to existing onshore substations. However, this would not rule out more detailed investigations into the possibility of adopting existing 132kV distribution network routes to the coast, such as that stretching from Norwich Main out to the coast near Great Yarmouth, if these were discovered to be the overall most economic and efficient solution in future.

Generation Sensitivities

98. As previously outlined, Sizewell is a connection point for an existing AGR nuclear generator. Currently a connection agreement is in place for the connection of new European Pressurised Water Reactor (EPR) nuclear generators at Sizewell as staged connections in 2016 and 2021. The capacity of these units would be in addition to the existing unit, which is not scheduled to decommission until 2035[19]. The Strategic Environmental Assessment for the next fleet of nuclear generators is yet to be completed, but this does not preclude the construction of reactors within similar timescales to the Round 3 offshore wind developments once it is complete. Although no formal decision on new nuclear at Sizewell has been taken the following transmission options have been considered, given its potential impact on Round 3 offshore wind connections:

a. Sizewell B only generating (1200MW; as per the non-contractual scenario).
b. Both Sizewell B and C generating (1200MW + 2 x 1650 MW; as per the contracted scenario).

99. As nuclear generation has an extremely low marginal cost of generating, it is normally run as 'base load' plant. Although wind generation is generally assumed to share a significant amount of transmission system capacity with conventional plant, this will normally not occur to the same extent with nuclear generation.

Transmission Reinforcements Required:

Wider System Reinforcement

100. The closest onshore connection points for the assumed locations of Southern Wash and East Anglia offshore wind generation developments are Norwich and Sizewell substations. Paragraphs 58 and 79 noted that reinforcement requirements are driven by a combination of Round 3 generation and the assumptions around existing onshore and offshore wind generation and potential conventional plant within a particular area of the transmission network. Therefore the results presented below are indicative and show a possible scenario of connection points for offshore generation.

Offshore Wind Connection Options and Issues

101. As explained above, only connections to existing onshore transmission substations have been considered for this region.

102. Walpole was one of the initial selected substations to be evaluated as a potential onshore connection point. However, the site is a considerable offshore distance from where Round 3 offshore generation developments are assumed to be located in this

[19] http://www.british-energy.com/pagetemplate.php?pid=96

region. In addition, the Wash is heavily environmentally designated. It is for these reasons that connection to Walpole is relatively less attractive to the other sites investigated at this stage, given the assumptions utilised, and is not considered further in this analysis.

Table 25: Connections into Substations Closest to Shore in East Anglia				
Total Offshore Generation Capacity (GW)	**Year (Notional)**	**Connection Configuration**	**Area Total Generation Capacity (GW)**	**Major Reinforcements Requirements**
25	2020/21	Maximum amount of wind into those substations closest to shore in East Anglia	5GW	Reconductor two Sizewell to Bramford circuits Create a new Pelham-Bramford overhead line + Create a second Bramford – Braintree-Rayleigh overhead line Reconductor the existing Bramford-Braintree-Rayleigh overhead line Establish a new east-west circuit between Walpole and the Cottam – Eaton Socon line

Potential Overhead Line and Substation Requirements

103. The increase in power flows arising from the connection of additional offshore generation in East Anglia leads to a requirement for transmission reinforcement along the southern stretch of the 400kV ring in this region over and above the significant reconductoring which is already assumed to have taken place, as outlined in Table 25.

104. The substation at Bramford would have to be replaced and the overhead line circuits coming into and around the site reconfigured, as the existing equipment at this site will no longer be able to facilitate the resulting power levels. A further double circuit overhead line route is also required from the new Bramford substation to increase the number of circuits on the western side from two to four. The general location of this additional circuit is illustrated in Figure 19, below. The final configuration would consist of two circuits from Bramford to Pelham and two circuits from Bramford to Rayleigh via Braintree. Additionally two of the circuits from Bramford to Sizewell and the existing Bramford-Braintree-Rayleigh circuit would need to be replaced with a conductor that has a higher current carrying capability (i.e. reconductoring as detailed in Appendix 1).

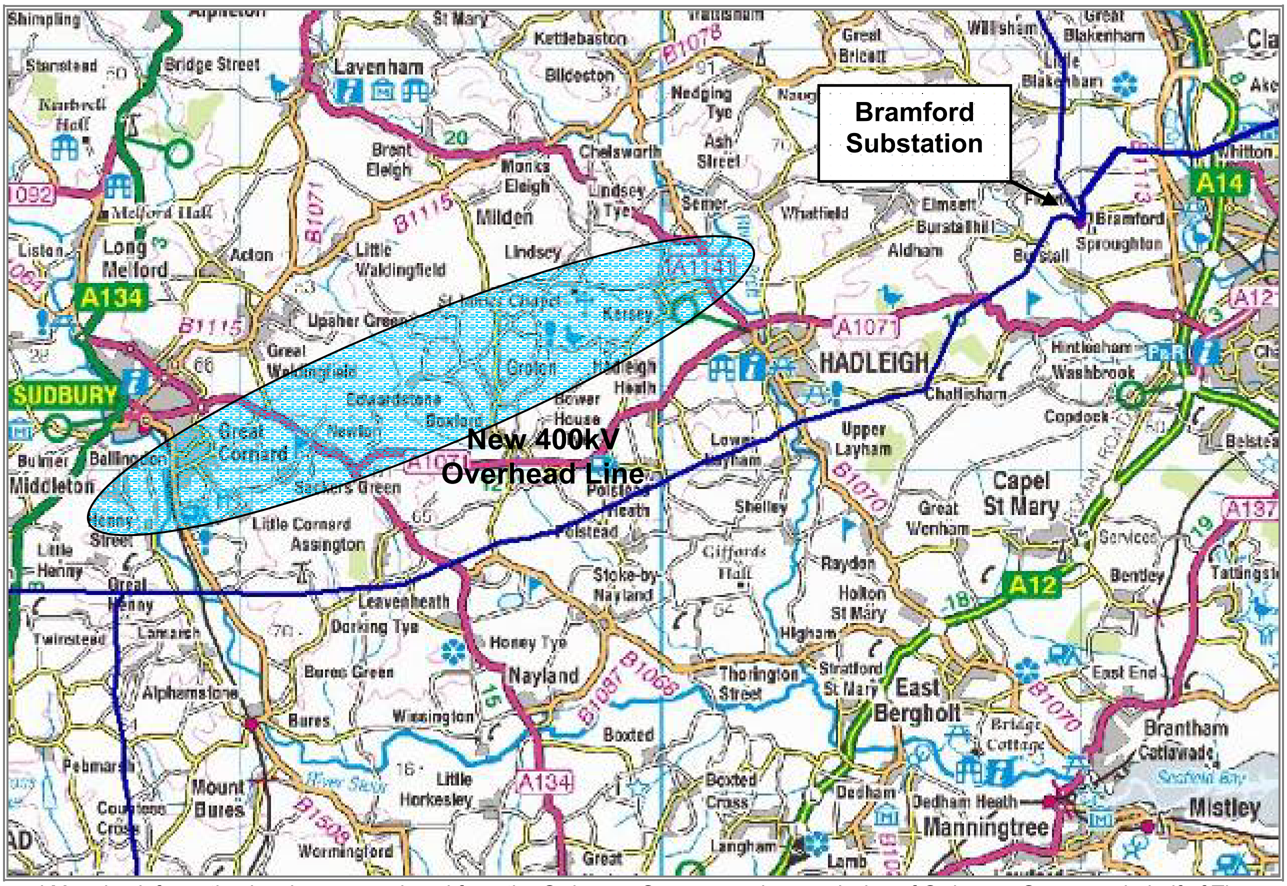


Figure 19 – New Overhead Line Requirements for Connection into East Anglia

Local Connection works and Associated Reinforcements

Table 26: Norwich Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Rural Area to the south of Norwich. Housing located 500m to the east. Extensive tree screening exists between properties and the substation. Consideration could be given to removing the existing DNO 132kV overhead lines to create space for developments. An environmentally sensitive area exists to the east of the substation location; between the site and the coast.
Onshore Transmission Works & Issues	Extend existing site, depending upon extent of connections this may require the expansion of the site to the west, triggering the need to purchase additional land, and obtain planning permission. DNO overhead lines may need to be diverted to facilitate offshore transmission equipment.
Offshore Transmission Works & Issues	Land may be available with existing National Grid ownership for the location of offshore transmission equipment, if the proposed 132kV substation area is vacant. HVDC converters will be located on site (as per Appendix 1)
Approximate Length of Cable Route from Coast	~39km
Impacts for Varying Levels of Installed Capacity	Extension of the site for two additional bays, as is required in the GB SQSS, will mean extension into greenfield. A single bay can be accommodated in the existing substation land area.
Indicative Onshore Transmission Costs	£10m
Estimated Timescales for ‘Local’ Onshore Transmission Work	4 to 5 years

Table 27: Sizewell Local Connection Work	
Existing Configuration	Indoor 400kV GIS Double Busbar
Local Environment	Existing onshore substation embedded in nuclear power station site. General area, covered by a range of environmental designations including AONB. Site surrounded by SSSI designation and within 2km of SPA and RSPB Reserves to the south. SPA and RAMSAR designations adjacent to the north.
Onshore Transmission Works & Issues	Limited scope to be able to extend existing substation. No apparent land area immediately adjacent for offshore transmission equipment. Possibility of having to build a new 400kV substation further inland outside of designated areas.
Offshore Transmission Works & Issues	Locating and connecting equipment; including HVDC converters. Possibility of AC connection into Sizewell subject to economic assessment at time of connection application. Acquiring land and obtaining planning permission.
Approximate Length of Cable Route from Coast	<1km
Impacts for Varying Levels of Installed Capacity	A single additional bay can be provided, and possibly a second at the opposite end of the existing substation. (2 are required to comply with the GB SQSS). A new substation is required to accommodate both nuclear replanting and the connection of Round 3 offshore wind generation.
Indicative Onshore Transmission Costs	£30m

Table 28: Rayleigh Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double busbar
Local Environment	Rural area in greenbelt between Rayleigh and Basildon. Adjacent to A130 new road development. Southend-on-Sea coastal area is an Important Bird Area, Special Protection Area (SPA) and RAMSAR site. Special Area of Conservation designation further west of Shoebury Ness.
Onshore Transmission Works & Issues	Extension of existing busbars at each end of the site. Need to move an existing overhead line to create space.
Offshore Transmission Works & Issues	Obtaining land and planning permission. Build of onshore interface equipment may be possible within existing onshore transmission owner land.
Approximate Length of Cable Route from Coast	~10km
Impact for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£10m
Estimated Timescales for 'Local' Onshore Transmission Work	4 years

Table 29: Barking Local Connection Work	
Existing Configuration	Indoor 400kV GIS Double Busbar
Local Environment	Urban area. Area subject to regeneration, with land surrounding substation being developed. Area of unoccupied National Grid land considered as local wildlife area.
Onshore Transmission Works & Issues	Extension to existing 400kV possibly requires a building extension. Ability to undertake without moving overhead line entries. Ability to obtain system access due to other developments and commitments.
Offshore Transmission Works & Issues	Obtaining land and planning permission. Only a limited area of land available; unlikely to be sufficient for the location of offshore terminus equipment. Connection requires laying of cable through the estuary and along the Thames river and will therefore be an extremely expensive offshore option.
Approximate Length of Cable Route from Coast	Connection requires laying of cable along the Thames river including necessity for relevant easements and wayleaves.
Impact for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£10m
Estimated Timescales for 'Local' Onshore Transmission Work	5 years (system outage availability permitting)

Table 30: Bramford Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	No local environmental designations.
Onshore Transmission Works & Issues	Site is scheduled to be replaced with an indoor double busbar GIS site. This is necessary prior to connection of any offshore generation. Achieving system outages to undertake rebuild changes, in time required.
Offshore Transmission Works & Issues	Possibility of laying subsea cable up the River Orwell into the south of Ipswich to reduce onshore cable distance (and associated costs). River has SSSI, RAMSAR and SPA designations.
Approximate Length of Cable Route from Coast	20km (assuming possibility of laying cable up the River Orwell)
Impact for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£ 10m
Estimated Timescales for 'Local' Onshore Transmission Work	6 – 7 years for re-build

Regional Sea 3 – Eastern Channel

Characteristics of Transmission network

105. As outlined at the start of the document, no offshore wind generation has been assumed to materialise in the Eastern Channel. However, due to developer interest in this area and depths of sea bed suitable for the placement of wind turbines, the onshore impact of connecting offshore wind has been considered in this area.

106. The onshore transmission system available to offshore wind generation for connection in this area is best explained as two distinct regions. The first, south of London and traversing Kent, East Sussex and West Sussex counties into Hampshire and the second extending further west from Hampshire into Dorest. Both regions are illustrated in Figure 20, below.

:

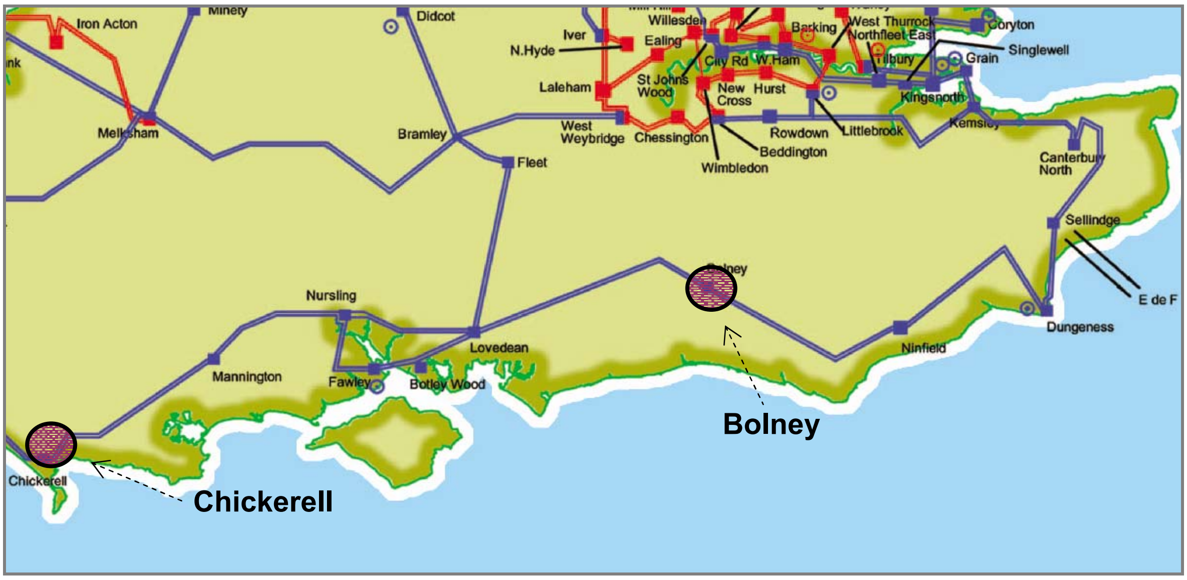


Figure 20– South Coast Onshore Transmission System

<u>Kent, East Sussex and West Sussex</u>

107. This part of the onshore system is characterised by one 400kV double circuit from Kemsley substation passing Canterbury North, Sellindge, Dungeness, Ninfield and Bolney before branching out into further routes at Lovedean. The significance of this single double circuit, is that the amount of generation connecting into this single route is limited by the need to cater for the loss of a double circuit overhead line route in planning transmission capacity (outlined in the GB SQSS). For the fault outage of a section of this double circuit route between Kemsley and the new Cleve Hill substation west of Canterbury North, all the generation connected southwest on this route will accumulate until it reaches Lovedean before it has further outlets onto the rest of the system.

108. No major onshore reinforcements have been identified for the connection of up to 500MW of offshore wind generation in this region against the 'non-contracted' scenario. For the connection of over 500MW a new overhead line route would likely be required.

109. The 'non-contracted' scenario assumes one new 1.6GW nuclear unit at Dungeness. This 1.6GW, coupled with any Round 3 offshore wind developments and a potential further 1.9GW import from the Anglo-French HVDC link would mean that if a second nuclear unit were to connect at Dungeness, a new 400kV OHL route would be required out of this region.

110. Against the contracted background, there would be no spare capacity on this part of the onshore transmission system. The timescales for connecting a project in this region would be impacted by those associated with any onshore transmission reinforcement requirements identified as part of a connection application.

111. The BritNed interconnector between the Isle of Grain in Kent and Maasvlakte, near Rotterdam in the Netherlands is currently in development and may also have an impact on this area of the network when energy is being imported from the Netherlands. This could also cause a 'loop flow' through the GB onshore transmission system between Grain and Sellindge substations, given the right economic conditions (i.e. relative electricity prices between Britain, France and the Netherlands).

112. Possible substations for connection to the onshore transmission system are Bolney and Ninfield. The impact of connecting into Bolney substation is highlighted in Table 31, below.

Hampshire and Dorset

113. The onshore transmission network in this area consists of a 400 kV double circuit transmission line that runs west from Nursling substation near Southampton, via substations at Mannington (inland from Bournemouth), Chickerell (Weymouth) and Axminster to Exeter. East of Nursling the line connects with generation sites at Fawley and Marchwood before branching out into the wider system at Lovedean substation near Portsmouth. The line route is closest to the coast between Chickerell and Axminster but otherwise lies several kilometres inland.

114. West of Exeter, the line continues to Indian Queens in Cornwall and then approximately follows the North Cornwall and North Devon coast back to Taunton. There it connects with another overhead line running directly from Exeter and a single double-circuit line then passes through Somerset to Hinkley Point and onwards to connect to the wider system at Melksham.

115. The transmission network must be designed and operated as required by the GB SQSS so that the loss of a section of double circuit line causes no overloading or other unacceptable system performance (as detailed in Appendix 3). Following such an outage on the line to the east of any wind farm connection into this part of the onshore network, the power from the wind farm would have to flow west to Exeter and then via Hinkley Point to Melksham. It would therefore combine with the power from generators at Langage, from any wind farms in the Bristol Channel and from nuclear generation at Hinkley Point. This combined power flow could be sufficient to trigger a need for significant reinforcements in this area of the network.

116. The extent and timing of these reinforcements is subject to the number of nuclear units assumed to be connected at Hinkley Point, the amount of offshore wind generation expected to be connected into the south west peninsula and the extent to which wind generation is assumed to share capacity with conventional generation in this area.

Transmission Reinforcements Required:

Local Connection works and Associated Reinforcements

Table 31: Bolney Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Rural area north of Sussex Downs. No local environmental area designations. Approximately 2km South-West of an AONB and further AONB between existing site and potential cable landing points.
Onshore Transmission Works & Issues	Extension of site will likely be contained within existing substation fence line. Minimal impact.
Offshore Transmission Works & Issues	Possibility of locating equipment in National Grid land, and planning consent. Large area of land adjacent to Bolney 400kV in National Grid ownership. Length of cable route and route identification from landfall.
Approximate Length of Cable Route from Coast	~21km
Impact for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£5m
Estimated Timescales for 'Local' Onshore Transmission Work	4 years

Table 32: Chickerell Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Mesh
Local Environment	On outskirts of Weymouth, closest housing approximately 300m distant. No environmental designations apply to immediate local area. Site is 1.5km from AONB and coastal area is RAMSAR and SSSI designated. Substation site landscaping achieved by cutting in hillside, and trees screening part of the site.
Onshore Transmission Works & Issues	Conversion of site to double busbar configuration required. This will utilise a large portion of the available land within National Grid ownership. System outage issues to undertake this work.
Offshore Transmission Works & Issues	Identifying suitable area of land for onshore portion of installation, land purchase and planning consent. Identifying suitable cable route around urban area and environmental designations
Approximate Length of Cable Route from Coast	~3km
Impact for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£15m
Estimated Timescales for 'Local' Onshore Transmission Work	5 – 6 years

Landing Points on South-West Peninsula

Characteristics of Transmission network:

117. To the south of the Bristol Channel, the network comprises a 400 kV double circuit running west from Taunton to Alverdiscott substation near Bideford and onwards to a substation at Indian Queens. A similar line runs eastwards from Indian Queens past substations near Plymouth and Exeter and continues to Nursling, near Southampton. For amenity reasons the lines are routed a few miles inland throughout their length.

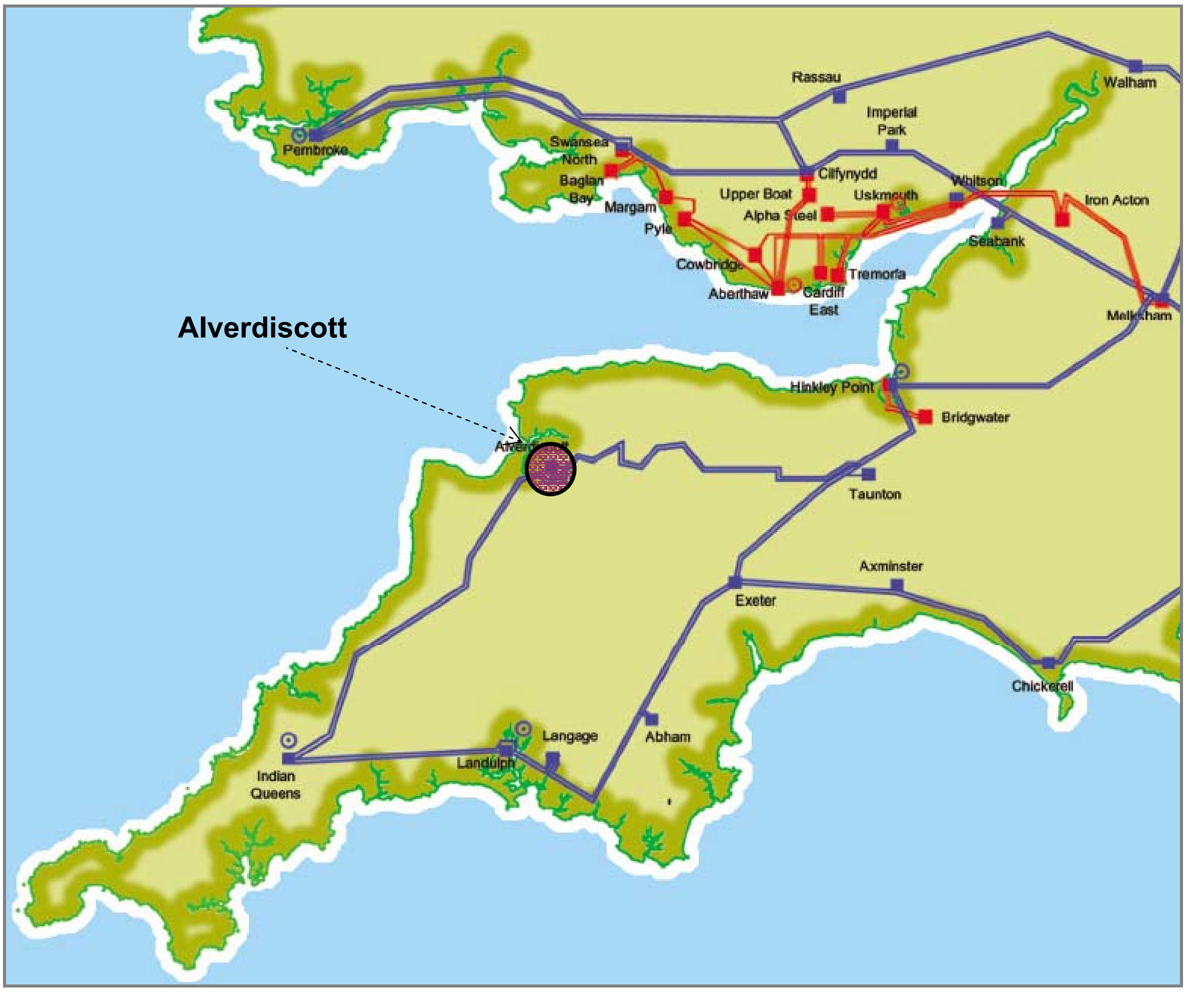


Figure 21 – South West Peninsula Onshore Transmission System

Offshore Wind Connection Options and Issues

118. The area west of Taunton/Exeter is a power-importing zone; there is no generation apart from the power stations at Langage (Plymouth) and a small gas turbine at Indian Queens. Up to 2 GW of new generation could be connected into the circuits between Taunton and Indian Queens without local reinforcement against the scenarios considered. Possible connection points for offshore wind generation, which is expected to be located in the Bristol Channel would be:

- Indian Queens (existing substation)
- Alverdiscott (existing substation)
- A new substation at East Yelland – on the coast near Bideford – connected to Alverdiscott
- One or more new substations connected into the line between Alverdiscott and Indian Queens

119. The assumed location and size of offshore wind developments in the Bristol Channel suggests Alverdiscott as the most favourable connection point. It has been assumed that the existing substation would be the most economic point of connection at this stage. The overall optimum solution is subject to economic assessment at the time of connection application.

120. For generation in the Western channel, possible connection points would be Axminster, Chickerell or one or more new substations on the circuits between them. As no offshore wind generation is assumed to materialise in this area, no further consideration of these sites is included in this study, beyond that for the connection of offshore wind generation located in the Eastern Channel, above.

Transmission Reinforcements Required:

Local Connection Works and Associated Reinforcements

Table 33: Alverdiscott Local Connection Work	
Existing Configuration	Outdoor 400 to 132kV transformers connected to existing overhead line (i.e. not a full substation)
Local Environment	Site situated within agricultural area. No environmental designations local to the site.
Onshore Transmission Works & Issues	A new 400kV outdoor double busbar substation is to be installed connected to the existing circuits and transformers. The 400kV overhead line entries will require moving to create the new connections to the existing substation.
Offshore Transmission Works & Issues	The equipment forming part of the offshore transmission system requires planning consent, and possibly additional land purchase, as there is little land available in the National Grid existing land ownership, after creation of the new 400kV substation.
Approximate Length of Cable Route from Coast	~5km
Impacts for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£35m
Estimated Timescales for 'Local' Onshore Transmission Work	5 years

121. For the wider peninsula, including Hinkley Point, reinforcement requirements would depend on the amount of wind generation connected, together with closure or replanting proposals for the nuclear generation at Hinkley Point. Hinkley Point 'B' will be over 40 years old by 2020 and may be anticipated to close before that date. However, the site may be used for one or more new EPR reactors with outputs in the region of 1600 MW each.

122. The existing transmission system can carry the output from one such EPR plus some 2 GW of wind, in addition to the generation at Langage with minor reinforcements such as reconductoring (as explained in Appendix 1). A major reinforcement (such as a new 400 kV overhead line from Hinkley Point to Seabank, near Avonmouth) would be triggered when a second EPR seeks to connect at Hinkley Point. Under the present Transmission Access regime, if the nuclear generator applies for connection before the offshore wind generation, the wind plant could not connect until the new line is commissioned. However, Transmission Access arrangements are currently under review so it is likely that more flexible arrangements will be in place before the decision to reinforce must be taken.

123. In this region an offshore wind generation project without a Crown Estate lease option already has a connection agreement in place for the connection of 1.5GW at Alverdiscott substation. In undertaking the analysis for this region, this 1.5GW was not assumed connected in the background in addition to the 2GW considered. (i.e. a maximum of 2GW of Round 3 offshore wind generation was considered)

Landing Points in South Wales

Characteristics of Transmission network:

124. In South Wales, two 400 kV double circuit lines run eastwards from Pembroke towards Swansea before diverging. A subsidiary 275 kV network connects Aberthaw power station and the load centres of Cardiff and south Glamorgan. There is new generation planned for Pembroke, and generation also at Baglan Bay near Swansea. The 275 kV network west of Aberthaw has insufficient capacity to carry any significant power from offshore wind. Against the scenarios considered, no offshore wind can be accommodated in South Wales without reinforcement of the network. For a given amount of wind generation, any connection in South Wales would thus be much more expensive than a connection in Devon or Cornwall.

Offshore Wind Connection Options and Issues

125. In view of the transmission constraints in South Wales, and since Alverdiscott is a practical and economic landing point for Bristol Channel wind, no South Wales landing points have been considered in this study.

Landing Points in North Wales

Characteristics of Transmission Network:

126. The closest onshore transmission network for the southern Irish Sea is comprised of a 400kV circuit ring in North Wales that connects Pentir, Deeside (near Connah's Quay) and Trawsfynydd substations. The majority of the overhead line loop around this region forms a double circuit route. However, only a single 400kV circuit connects Pentir to Trawsfynydd within Snowdonia national park which is the main limiting factor for capacity in this area.

127. There is a double circuit spur (approximately 36km) out to the coast from Pentir to Wylfa Head near Cemaes that crosses the Menai Sraight. Wylfa substation is currently a connection site for the 980MW Wylfa A Magnox nuclear power station. It is anticipated that Wylfa A station will begin decommissioning by 2010, hence it is omitted from the assumed generation and demand scenarios. There is also a double circuit cable spur (route length approximately 10km) from Pentir that connects Dinorwig pump storage station by Llyn Peris reservoir. A 275kV spur (approximately 7km) traverses north of Trawsfynydd to Ffestiniog pumped storage station.

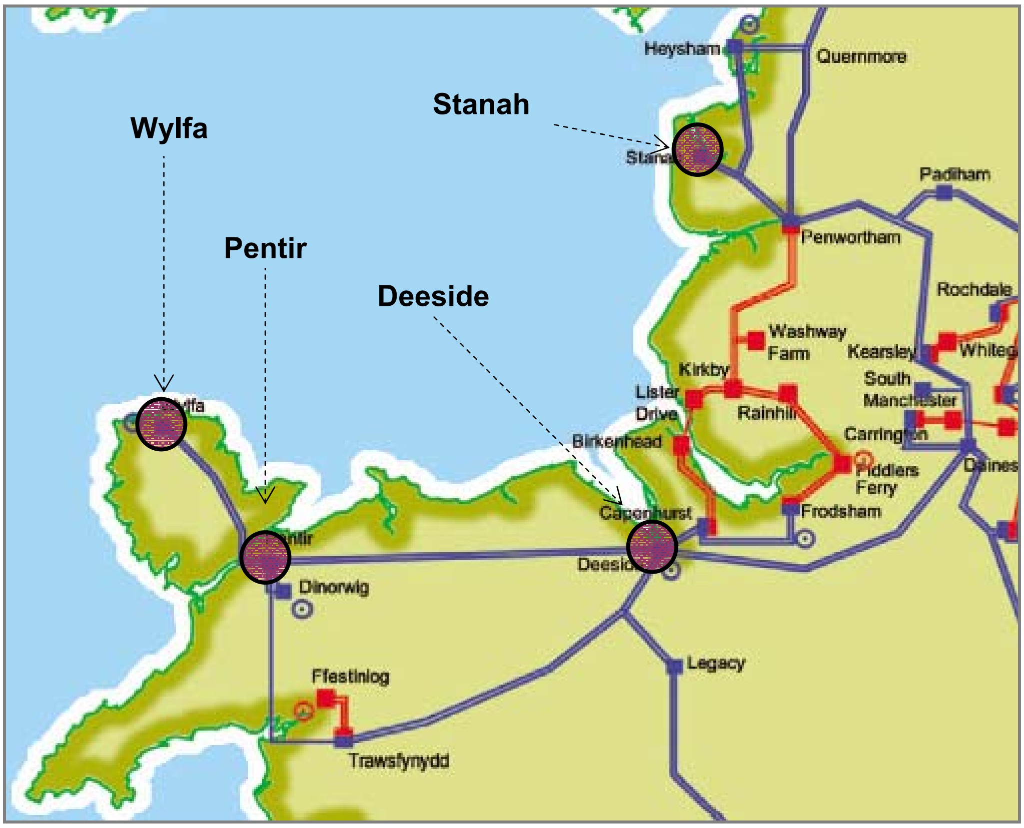


Figure 22 – Onshore Transmission System in North Wales and the North West

128. Currently, the transmission system in north Wales is being modified to allow for the connection of the Round 2, Gwynt-y-Mor offshore wind generation development. The current proposals for this connection are to construct a new 400kV substation to the north east of Deeside linking to the main transmission system via a double circuit between Pentir and Deeside.

129. The scenarios used assume some existing CCGT plant at Deeside has decommissioned (Connah's Quay and Deeside Power), while Dinorwig and Ffestiniog pumped storage plants continue to remain in service. The total amount of existing plant closures in this region is

assumed to be 1885MW in the non-contractual scenario and hence some existing transmission capacity is released by these closures against this background.

Offshore Wind Connection Options and Issues

130. Various options exist for the connection of offshore wind generation into North Wales. The final optimum solution is highly dependent on what happens with other developments progressing in the region. The assumed HVDC link from Hunterston into Deeside as well the connection of the East-West interconnector and potential for nuclear generation in this area all have the potential to interact with offshore wind generation developments. Assumptions on the closure of existing and opening of new conventional plant may also affect the optimum connection solution.

131. The scenarios assume that up to 4GW may connect in this area. One option for the connection of this offshore wind generation may be to connect to substations on the extremities of the onshore transmission system. This may allow for the use of AC rather than DC technology and may also facilitate shorter offshore cable lengths, hence reducing the cost of the offshore network.

132. A further option is to split the total volume of offshore wind assumed between the nearest substations (which are not as strongly connected to the remainder of the network) and those substations that may be further away from the location of the offshore wind projects, but have stronger connections to the onshore network.

Wider System Reinforcement

133. It is assumed that the total volume of offshore wind will be spread across existing substations near to the coast in North Wales. Major reinforcement options are identified in Table 34 below.

North Wales Wind Connection Options and System Reinforcement Requirements for Assumed total of 4GW Round 3 Offshore Wind Generation

Table 34: Option A - Connections into Western Coastal Substations in North Wales				
Total Offshore Generation Capacity (GW)	**Year (Notional)**	**Connection Configuration**	**Area Total Generation Capacity (GW)**	**Major Reinforcements Requirements**
20	2019/20	Connections into substations located in the North West of Wales	4GW	Second Pentir – Trawsfyndd circuit on existing OHL route Potential requirement for new OHL from Wylfa to Pentir (if new nuclear generation connecting at Wylfa)

Table 35: Option B - Connections Split Across Coastal Substations in North Wales				
Total Offshore Generation Capacity (GW)	**Year (Notional)**	**Connection Configuration**	**Area Total Generation Capacity (GW)**	**Major Reinforcements Requirements**
20	2019/20	Connections into substations located in the North West and North East of Wales	4GW	Reconductoring work required in the vicinity of connection in north east of Wales Significant interaction with other developments in the region

134. If both offshore wind generation and nuclear generation seek to connect in similar timescales, it may be necessary to establish a new overhead line between Wylfa and Pentir substations. The need for this OHL would be dependent on the location of offshore wind projects and the amount of generation seeking to connect on Anglesey.

Potential Overhead Line and Substation Requirements

Background Mapping information has been reproduced from the Ordnance Survey map by permission of Ordnance Survey on behalf of The controller of Her Majesty's Stationery Office.©Crown Copyright Ordnance Survey.National Grid Electricity - 100024241.

Figure 23 – Possible New Overhead Line Requirement in North Wales

135. Possible connection points for offshore wind investigated include:

- Wylfa (existing substation)
- Deeside (existing substation)
- Pentir (existing substation)

Transmission Reinforcements Required:

Table 36: Wylfa Local Connection Work	
Existing Configuration	Indoor 400kV AIS Double Busbar
Local Environment	Power station site on the coast of Anglesey. No environmentally designated sites in the vicinity.
Onshore Transmission Works & Issues	Need for weather protected equipment, and extending existing switchgear probably to be undertaken in GIS.
Offshore Transmission Works & Issues	Obtaining location for offshore transmission equipment, as very limited space available. Land and planning permissions required.
Approximate Length of Cable Route from Coast	< 1km
Impact of Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£10m
Estimated Timescales for 'Local' Onshore Transmission Work	4 to 5 years

Table 37: Deeside Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar – However due to be asset replaced by indoor GIS
Local Environment	Power station site, brownfield area, adjacent to River Dee Environmentally designated (SSSI, SAC, etc) areas adjacent to existing site.
Onshore Transmission Works & Issues	New substation planned to be installed, which will release further land area. The spare land may be required for other projects, particularly if a Scottish DC link is terminated at Deeside
Offshore Transmission Works & Issues	Location and connection of equipment. Cable routes and constraints of river Dee. Availability of land could be an issue. Cable route - need to identify if it is possible to install in the river Dee estuary, or if overland route required.
Approximate Length of Cable Route from Coast	< 1km
Impact for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£25m
Estimated Timescales for 'Local' Onshore Transmission Work	5 years

Table 38: Pentir Local Connection Work	
Existing Configuration	Outdoor Double Busbar AIS
Local Environment	Rural land south-east of Bangor. Site is located in an area of woodland.
Onshore Transmission Works & Issues	Possible need to extend fence-line to achieve bay extensions. If second Trawsfynydd circuit to be created, wider substation works required.
Offshore Transmission Works & Issues	Location for offshore TO equipment land availability and planning permission.
Approximate Length of Cable Route from Coast	6km
Impacts of Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£5m
Estimated Timescales for 'Local' Onshore Transmission Work	4 years (excluding addition of second circuit to Trawsfynydd)

Landing Points in Merseyside

Characteristics of Transmission Network:

136. The north Irish Sea area consists of a 400kV double circuit transmission ring (Heysham ring) that links Hutton, Heysham, Stanah and Penwortham substation sites. Currently there are two 1200MW nuclear generation units connected at Heysham. The scenarios used for this study assumes Round 2 offshore wind generation at Stanah and Heysham with one nuclear generation unit decommissioned.

137. This part of the transmission network forms one of the major routes that allows power to flow form Scotland to regions further south in England and Wales. To facilitate increased power transfers from Scotland as well as the generation contributed from anticipated Round 2 offshore wind generation, the Heysham ring circuits are being reconductored. This reinforcement is TIRG related (i.e. part of the 'Transmission Investment for Renewable Generation' initiative) and an assumed reinforcement in the study background.

138. As a result of this overhead line reconductoring assumed to have completed, in conjunction with the west coast HVDC link from Hunterston to Deeside relieving north to south power flows on the onshore circuits, no wider system reinforcements are required in this region.

139. Should the assumed HVDC link from Hunterston to Deeside not go ahead, the available capacity assumed in this area due to a shifting of north to south power flows would no longer be available and offshore wind generation may need to connect into North Wales as an alternative.

Local Connection works and Associated Reinforcements

140. Possible connection points investigated for offshore wind are:

- Heysham (existing substation)
- Stanah (existing substation)

141. Both Heysham and Stanah are coastal sites and any transmission equipment associated with the offshore wind developments would need to traverse environmentally designated areas to connect onshore. Similarly both sites are roughly equidistant from the assumed offshore development zone.

Table 39: Heysham Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Double Busbar
Local Environment	Rural environment bounded by local infrastructure. <1km southwest from a small SSSI designated area Coastal area is RAMSAR, SPA, SAC and SSSI designated.
Onshore Transmission Works & Issues	Extension works would have to be contained within existing fence line due to local constraints. Minimal space or extension available.
Offshore Transmission Works & Issues	Ability to obtain land to locate equipment in vicinity of National Grid substation could be problematic.
Approximate Length of Cable Route from Coast	~ 3km
Impact for Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£10m
Estimated Timescales for 'Local' Onshore Transmission Work	4 – 5 years

Table 40: Stanah Local Connection Work	
Existing Configuration	Outdoor 400kV AIS Transformers Feeders
Local Environment	Urban area, adjacent to industrial area – ex-chemical works, brownfield areas. Substation enclosed on 3 sides by domestic housing and a caravan park. Site is <0.5km from the River Wyre which is RAMSAR and SSSI designated.
Onshore Transmission Works & Issues	Need to introduce 400kV GIS substation, site issues to create in space desired. Issues of co-ordination with offshore transmission owner, access routes, future development constraints, planning permissions. System outage issues to permit construction/connection
Offshore Transmission Works & Issues	Space for equipment, may require location of installation on brown-field land North West of substation. Issues of land availability, Cable access routes, program, planning permission and noise levels.
Approximate Length of Cable Route from Coast	~4km directly west to coastline
Impact of Varying Levels of Installed Capacity	2 substation bays required for developments up to 1.1GW, given technology and optimisation assumptions used
Indicative Onshore Transmission Costs	£30m
Estimated Timescales for 'Local' Onshore Transmission Work	5 years

4. Potential Build Up – Possible Timing of Onshore Reinforcements

142. Utilising the results of the investigation into the environmental and cost impact of connecting offshore wind generation projects to the potential onshore connection sites described above (i.e. the 'local connection work') and the assumed distribution of a further 25GW of total wind energy in the Renewable Energy Zone (presented in Section 2), a possible build order for the various offshore regions was put together. This was done to allow for an investigation of the incremental impact of connecting 5, 10, 15, 20 and 25GW additional to approximately 8GW already planned, thus assuming a 33GW total of offshore wind generation.

143. Those sites closer to shore and easier to develop were assumed to do so first, whilst others will come on line incrementally as the total increases towards 25GW. The report assumes that the Dogger Bank in particular would be developed towards the later stages due to its distance from the onshore transmission system and associated increased cost of connection.

144. The potential build up in Table 41 has assumed some parallel development of the offshore areas taken as suitable for offshore wind generation. It is for this reason that projects in the Dogger Bank are not left until the final 25GW step. If a further 25GW of offshore wind generation was to be developed within a limited time period, it may be necessary to further spread the assumed build up of GW more evenly across the areas considered. This could lead to the 'wider system' onshore transmission reinforcements identified being required earlier than anticipated in the commentary that follows.

Table 41: Potential Build-up of Round 3 Offshore Wind Generation

Regional Sea		Area	Offshore Incremental Installed Capacity (GW):					Regional Sea Total (GW)
	Overall Total (GW) Installed		5	10	15	20	25	
1	Northern North Sea	Moray Firth	0	0	0	0.5	1	**2**
		Firth of Forth	0	0	0	0.5	1	
2	Southern North Sea	Dogger Bank	0	0	3	4	8	**16**
		Greater Wash	1	3	3	3	3	
		East Anglia	1	2	3	5	5	
3	Eastern Channel	South Coast	0	0	0	0	0	**0**
4	Western Channel & Celtic Sea	Bristol Channel	2	2	2	2	2	**2**
6	Irish Sea	North Wales	1	2	3	4	4	**5**
		North West	0	1	1	1	1	

145. As illustrated in Table 41 above, the build up is characterised by a significant amount of activity in the Southern North Sea (Regional Sea 2), Western Channel & Celtic Sea (i.e. Regional Sea 4), and Irish Sea (i.e. Regional Sea 6) areas in the early part of the programme up to 15GW of capacity. In the later stages, up to 25GW of total offshore generation capacity from further rounds of wind leasing, the volume of installations pick up considerably within the Southern North Sea (Regional Sea 2) and also include the Northern North Sea (Regional Sea 1) area as illustrated in the relative build-up chart, below.

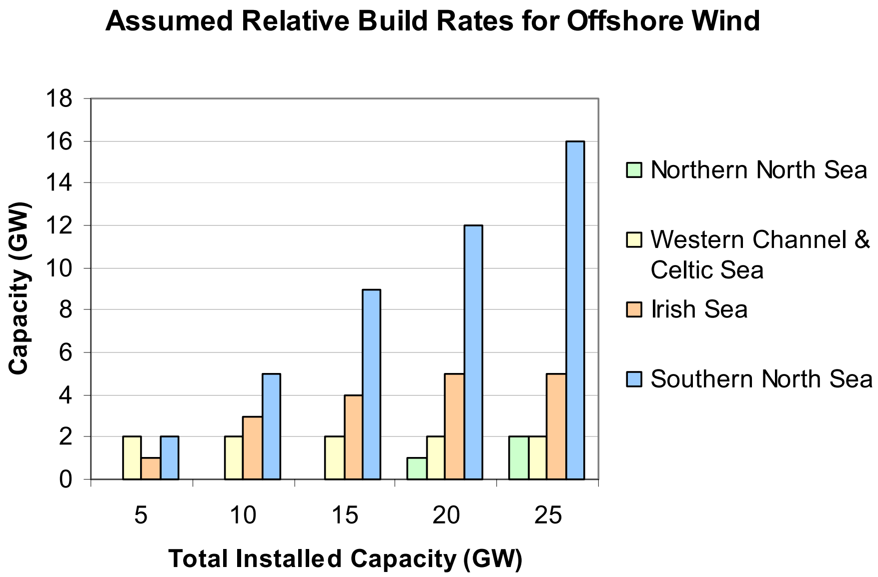


Figure 24 – Assumed Relative Build Rates for Offshore Wind

146. A change in the assumed distribution and build up of generation will effect the onshore reinforcement requirements and their timing. However, a coordinated approach to the development of optimised connections for Round 3 offshore wind generation would help to mitigate this change.

Regional Sea 1 – Northern North Sea

147. As the Scottish offshore sites are assumed to be developed towards the end of the total 25GW, the necessary reinforcements to the onshore transmission system should already be in place to facilitate their connection. These reinforcements are predominately driven by the amount of onshore wind expected to arise in Scotland and are currently the subject of investigation through the collaborative study being undertaken by onshore transmission owners under the ENSG, as described in further detail in Section 5, below.

Regional Sea 2 – Southern North Sea: Dogger Bank and Northern Wash

148. The Dogger Bank and 'Northern Wash' offshore wind sites are the most distant from the mainland of all the areas considered. It is assumed that they are more likely to be among the last to be developed, since developers may favour the easier, cheaper locations first and tackle the more difficult projects as experience and technology improves.

149. As discussed earlier, the requirements for system reinforcement depend on the rate of generation build-up in an area, the exact sites chosen for connection, and the underlying power flows in the system due to generation elsewhere. The report considers combinations of wind generation connection sites in the tables below.

Table 42: Option A – Inland and Coastal Connection Sites

Total Capacity (GW)	Year (Notional)	Connection Site	Amount (GW)	Zonal Total (GW)	Major Reinforcement Requirements
5	2014/15	Keadby	1.1	1	Extend existing substation
10	2015/16	Keadby Killingholme	2.2 1.1	3	Further extend existing and establish a new substation
15	2016/17	Creyke Beck Keadby Killingholme Thornton	1.1 2.2 2.2 1.1	6	Reconductor Drax-Eggborough overhead line
20	2018/19	Creyke Beck Keadby Killingholme Thornton	2.2 2.2 2.2 1.1	7	Uprate Brinsworth – Chesterfield 275 kV line to 400 kV, build a new 400 kV substation at Chesterfield and a new 400kV overhead line from Chesterfield to Willington
25	2020/21	Creyke Beck Keadby Killingholme Thornton Drax	2.2 2.2 2.2 2.2 2.2	11	As above + new 400 kV overhead line from Creyke Beck to Drax substation

Table 43: Option B – Mostly Coastal Connection Sites

Total Capacity (GW)	Year (Notional)	Connection Site	Amount (GW)	Zonal Total (GW)	Major Reinforcements Requirements
5	2014/15	Keadby	1.1	1	None
10	2015/16	Keadby Killingholme	2.2 1.1	3	Minimal
15	2016/17	Creyke Beck Keadby Killingholme Grimsby West	2.2 2.2 1.1 1.1	6	None (based on Killingholme + Grimsby ≤ 2.2 GW for S. Humber circuits to be compliant with security standards)
20	2018/19	Creyke Beck Keadby Killingholme Grimsby West	2.2 2.2 2.2 1.1	7	New 400kV overhead line from Grimsby West to Bicker Fen or Walpole substations (Lincolnshire coast)* + new 400kV overhead line from Bicker Fen or Walpole to a new substation near Peterborough on the Cottam-Eaton Socon line
25 (a)	2020/21	Creyke Beck Keadby Killingholme Grimsby West	3.3 2.2 3.3 2.2	11	As for 20 GW, + new 400 kV overhead line from Creyke Beck to Drax substation
25 (b)	2020/21	Creyke Beck Keadby Killingholme Grimsby West	2.2 2.2 4.4 2.2	11	As for 20 GW, + new 400 kV overhead line from Killingholme to West Burton substation

150. No environmental impact analysis has been carried out for the above reinforcement options at this stage.

Regional Sea 2 – Southern North Sea: Southern Wash and East Anglia

151. The Southern Wash and East Anglia offshore wind sites are a shorter distance from potential onshore connection points than the Northern Wash zone and as such may be more likely to be developed in the earlier years.

152. Table 44: considers combinations of offshore wind generation connection sites assuming substation extensions at easier sites (closer to the offshore wind generation) will be developed first and major onshore reinforcements are minimised.

East Anglia Wind Connection Options and System Reinforcement Requirements for Possible 'Round 3' Wind Build-up

Table 44: East Anglia Reinforcements without Sizewell C					
Total Capacity (GW)	**Year (Notional)**	**Connection Site**	**Amount (GW)**	**Zonal Total (GW)**	**Major Reinforcements Requirements**
5	2014/15	Norwich	1.1	1	Extend existing substation
10	2015/16	Norwich Sizewell	1.1 1.1	2	Extend existing substations and rebuild of Bramford substation.
15	2016/17	Norwich Sizewell	2.2 1.1	3	Reconductor both Sizewell to Bramford circuits, New section of overhead line (OHL) between Bramford and Twinstead to create a new Pelham – Bramford OHL, and a second Bramford – Braintree – Rayleigh OHL, Reconductor the existing Bramford-Braintree-Rayleigh OHL route
20	2018/19	Norwich Sizewell Rayleigh/Bramford	2.2 2.2 1.1	5	As above
25	2020/21	Norwich Sizewell Rayleigh/Bramford	2.2 2.2 1.1	5	As above

153. With respect to the assumed connection point build up as shown above, when there is between 1 – 2GW of offshore wind connecting in East Anglia, a new substation at Bramford would have to be constructed due to the resultant increase in power transfer that is in excess of the equipment rating of the existing substation and overhead line configuration. If this new substation at Bramford is constructed, it could serve as a more attractive alternative connection site to Rayleigh. Connection into Bramford would reduce the cost of the assets forming part of the offshore transmission system, but may require additional reinforcements to those listed above against certain background conditions.

154. Against the 'non-contractual' background (with no new nuclear at Sizewell), in the order of 3GW of additional generation can connect into the onshore transmission network in East Anglia without the need for new overhead lines. However, as outlined above, significant work is required at Bramford substation to reconfigure circuits and replace substation equipment before this level of generation can connect.

155. Given a general program of 5 to 7 years for a new overhead line build and an assumption that much of the substation work at Bramford could be done in parallel with this, detailed development work for the reinforcements highlighted would need to begin in 2009 to meet the build up stated. Should the assumed 1 to 2 years for obtaining planning consents deviate significantly; this would have a direct impact on the ability to deliver the onshore network capacity in time.

East Anglia Wind Connection Options and System Reinforcement Requirements for Possible 'Round 3' Wind Build-up with Sizewell C nuclear generation

Table 45: East Anglia Reinforcements with Sizewell C

Total Capacity (GW)	Year (Notional)	Connection Site	Amount (GW)	Reinforcements Requirements
5	2014/15	Norwich	1.1	All major reinforcements highlighted in Table 44 required for connection of nuclear generation. This then provides a further 2 to 3 GW of capacity in this region.
10	2015/16	Norwich Sizewell	1.1 1.1	
15	2016/17	Norwich Sizewell Rayleigh/Bramford	1.1 1.1 1.1	
20	2018/19	Norwich Sizewell Rayleigh/Bramford Barking	1.1 1.1 1.1 2.2	Connection into Barking investigated as option to avoid onshore reinforcement; Alternative is to build a new overhead line between Walpole and the Cottam – Eaton Socon line as highlighted for Dogger Bank and Northern Wash connections.
25	2020/21	Norwich Sizewell Rayleigh/Bramford Barking	1.1 1.1 1.1 2.2	

156. The introduction of Sizewell C nuclear generation triggers significant transmission system reinforcements out of the East Anglia area, the need for which extends further south towards Essex. The reinforcements assume Sizewell B nuclear plant continues to generate when Sizewell C connects and are as highlighted in Table 44 and Table 45 with the addition of reconductoring of the existing Rayleigh-Coryton-Tilbury overhead line route.

157. Table 45 shows a possible build up of offshore wind when both Sizewell B and Sizewell C nuclear plants are generating. The table below has split the offshore wind such that no further onshore reinforcement is required over and above that for the Sizewell C application alone. In other words, by reducing the amount of Round 3 offshore wind generation connecting in East Anglia, no further transmission reinforcements are triggered by the Round 3 offshore wind; the offshore wind shares the increased incremental capacity provided by the same reinforcements.

158. Connecting the Round 3 offshore wind at Rayleigh or Barking eliminates further onshore reinforcement out of the East Anglia group by linking generation to the high demand centres in London more closely. However, the significant increase in offshore transmission costs, consents, wayleaves and land issues (for Barking) associated with these options mean that they are likely to be unattractive compared to the alternative of onshore reinforcement.

159. This alternative onshore reinforcement, between Walpole and the existing Cottam – Eaton Socon overhead line route, was also identified as an option to accommodate the connection of offshore wind generation from the Dogger Bank and Northern Wash areas.

160. No environmental impact analysis has been carried out for the above reinforcement options at this stage.

Regional Sea 3 – Eastern Channel

161. No offshore wind generation is assumed to be developed in the Easter Channel Regional Sea. This area is therefore not discussed further.

Regional Sea 4 – Western Channel and Celtic Sea

162. Due to its proximity to shore and the associated lower connection cost for developing this area, a connection to Alverdiscott is assumed within the first year of the build-up. All 2GW for this area is assumed to be developed at the same time.

Table 46: South West Peninsula

Total Capacity (GW)	Year (Notional)	Connection Site	Amount (GW)	Zonal Total (GW)	Major Reinforcements Requirements
5	2014/15	Alverdiscott	2	2	Build full substation at Alverdiscott
25	2020/21	n/a	0	2	n/a

163. No wider onshore network reinforcements have been identified for this level of offshore wind generation connecting in this region.

164. A bilateral connection agreement is in place for the connection of 2 EPR nuclear generators at Hinkley Point in addition to the existing Hinkley Point B station. Should Hinkley be identified as suitable through the relevant Strategic Environmental Assessment and both these nuclear developments progress along the same timescales as offshore wind generation, additional system capacity, in the form of new overhead line routes will be required.

165. A new overhead line route between Hinkley Point and Seabank (at approximately 60km in length) has been identified as one reinforcement option for this generation background.

Regional Sea 6 – Irish Sea

Landing Points in North Wales

166. Table 47: Option A – South Irish Sea and Table 48 present two approaches to providing connections for offshore wind generation in this area. Option B is to connect into Deeside and avoid major onshore reinforcement at a higher cost offshore and at a risk of insufficient space at Deeside substation due to interaction with other developments.

167. The currently preferred option, Option A, is to undertake investment in the Pentir – Trawsfynydd second circuit before user commitment is in place so that the capacity will be available when the wind generation is ready to connect. This circuit, required for the connection of more than 1GW of additional generation in this region, would allow for an

overall optimum solution to be developed between the offshore and onshore reinforcement requirements.

168. In order for a second Pentir – Trawsfynydd circuit to be available for Round 3 offshore wind to connect, detailed development would have to begin in 2009/10, given the planning consents timescales assumed in Figure 1 – Break Down of Project Delivery Timeline.

169. Subject to the location of the offshore wind generation and further analysis of the optimum combined offshore and onshore solution, it may be economical to connect more generation into Wylfa than is shown in Table 47: Option A – South Irish Sea. Such a connection would require a new section of overhead line between Wylfa and Pentir substations, across Anglesey as shown in Figure 23. This option may reduce the cost of the offshore network.

South Irish Sea Wind Connection Options and System Reinforcement Requirements for Possible 'Round 3' Wind Build-up

Table 47: Option A – South Irish Sea Connections into North West Wales

Total Capacity (GW)	Year (Notional)	Connection Site	Amount (GW)	Zonal Total (GW)	Major Reinforcement Requirements
5	2014/15	Wylfa	1	1	None
10	2015/16	Wylfa Pentir	1 1	2	Second Pentir – Trawsfyndd circuit required (would include third party work)
15	2016/17	Wylfa Pentir	1 2	3	None (potential to connect more generation at Wylfa would require extra circuit between Wylfa and Pentir)
20	2018/19	Wylfa Pentir	1 3	4	None
25	2020/21	n/a	0	4	n/a

Table 48: Option B – South Irish Sea Connections Across North Wales

Total Capacity (GW)	Year (Notional)	Connection Site	Amount (GW)	Zonal Total (GW)	Major Reinforcement Requirements
5	2014/15	Wylfa	1	1	None
10	2015/16	Wylfa Deeside	1 1	2	Significant local works at Deeside
15	2016/17	Wylfa Deeside	1 2	3	Some reconductoring and reconfiguration of circuits out of Deeside
20	2018/19	Wylfa Deeside	1 3	4	Potential for significant offshore costs (depending on location of wind)
25	2020/21	n/a	0	4	n/a

170. The major onshore transmission reinforcements highlighted in Table 47 could provide the optimum solution, depending on the location of offshore wind projects in the Irish Sea. The

second circuit on the Pentir to Trawsfynydd route would also be required for the connection of new nuclear generation at Wylfa substation.

171. No environmental impact analysis has been carried out for the above reinforcement options at this stage.

Landing Points in Merseyside

172. Congestion on this part of the system is building as more generation capacity is developed in Scotland and must travel south on a limited number of circuits. The offshore HVDC link assumed to be in place between Hunterston and Deeside relieves power flows on the onshore system and therefore there is no major wider system impact onshore. If this link were not in place, a significant amount of onshore reinforcement around the Mersey area would have to take place. Much of this would be in urban areas.

173. The Round 3 offshore wind development build-up could be such that 1GW connects in this zone in 2015 or 2016 with the decommissioning of the Heysham 1 unit predicted in 2018 as given in the 'non-contractual' background. In this instance it would not be possible for the Round 3 wind generation to utilise any of the existing substation assets released by the nuclear generator that could remove the need for substation extension. Should the decommissioning of Heysham occur before the Round 3 wind generation connects, the wind generation may be able to connect at Heysham without significant construction work.

174. The existing Stanah site currently serves to supply demand to the local DNO with two 400/132kV transformers taken from the Heysham ring circuits, hence the site will have to be developed for the connection of Round 2 wind generation alone. It is surrounded on three sides by a caravan park, residential housing and an industrial area that limits the extent of any further expansion within and immediately outside the National Grid site boundary.

175. Due to the closure of the Heysham 1 unit in the generation background assumed, the Round 3 offshore wind benefits from this release in transmission capacity in this local part of the system.

North Irish Sea Wind Connection Options and System Reinforcement Requirements for Possible 'Round 3' Wind Build-up

Table 49: North Irish Sea					
Total Capacity (GW)	Year (Notional)	Connection Site	Amount (GW)	Zonal Total (GW)	Major Reinforcement Requirements
5	2014/15	-	0	0	-
10	2015/16	Heysham/Stanah	1	1	Extend existing substation only
25	2020/21	n/a	0	1	n/a

176. If the Heysham 1 unit life is extended further than assumed, there may be difficulty in connecting generation in this area.

5. Initiatives Currently Underway

Transmission Access Review (TAR)

177. Access arrangements for entry to the electricity transmission system are currently under review through several initiatives ranging from short to medium term incremental changes to those addressing long term fundamental change. Following publication of the Energy White Paper 2007, Ofgem and BERR convened a joint review of the current framework for access to the GB transmission system under the 'Transmission Access Review' (TAR) heading. The review was to explore a range of issues associated with the technical, commercial and regulatory arrangements, with the chief aim being to better support the delivery of the targets agreed at a European level translated to approximately 30 – 40% percent of electricity supplied by renewable generation by 2020.

178. The type of changes that are eventually implemented could have a significant impact on the connection dates of new generation projects as operational measures are used to manage system security rather than additional capacity in the short term. A change in the way access to the system is allocated, along with a regulatory mechanism to incentivise strategic investment in additional transmission capacity is necessary in order to enable the levels of wind generation required to meet government targets and at the same time balance the operational costs with those of building additional transmission capacity.

179. The models of transmission access reform being considered are:

i) Connect and Manage	
Access allocation	• Allocate then invest for long-term rights when accompanied by suitable long-term commitment • Eligibility criteria must be met (e.g. [3] years after connection offer accepted; local works complete
Secondary trading	• No secondary trading
Nature of rights	• Nodal long-term rights
Pricing	• Full TNUoS 'local, 'wider' and 'residual'

ii) Evolutionary Change	
Access allocation	• Invest then allocate for long-term rights when accompanied by suitable long-term commitment • Short-term rights identified and auctioned by SO • Overrun
Secondary trading	• Sharing allowed in pre-defined zones with 1:1 sharing factor
Nature of rights	• Zonal short or long-term rights for a defined period
Pricing	• Full TNUoS 'local, 'wider' and 'residual'

iii) Capacity Auctions	
Access allocation	• Long-term rights (invest then allocate) auctioned • Suitable long-term commitment required for incremental capacity • Short-term rights identified and auctioned by SO • Overrun
Secondary trading	• Sharing allowed in pre-defined zones with 1:1 sharing factor
Nature of rights	• Zonal short or long-term rights for a defined period
Pricing	• Residual (£/kW) and local asset charge • "Pay as bid" for long-term • "Pay as bid" for SO released; ex post SRMC for • Overrun

180. The implementation date for the relevant reform proposals is April 2010. There has been significant commitment from industry participants in their development and a high level of engagement and expertise is moving thinking forward.

Fundamental Review of the GB Security and Quality of Supply Standards

181. The GB SQSS, and accordingly the GB transmission system, needs to continually evolve to keep pace with changing requirements placed upon it. The GB SQSS Review Group has been charged with the responsibility of ensuring the GB SQSS is modified in a timely fashion such that it continues to meet the challenges arising from developments within the electricity supply industry and from technological advances.

182. There are a number of review requests currently being considered or that are waiting to be considered by the GB SQSS Review Group. Each of the above review requests and developments has the potential to have a material affect on the GB SQSS. Given the range and interdependencies of the review requests, the GB SQSS Review Group has determined that these issues are most efficiently addressed on a holistic, rather than on a piecemeal, basis.

183. Accordingly, the objective of this project is to undertake a 'Fundamental Review' of the GB SQSS and develop appropriate change proposals to address all relevant issues whilst taking due account of interactions between issues, including external reviews, which have the potential to impact on the GB SQSS (e.g. TAR).

184. One aspect of this review will include how transmission capacity is planned for a system with high volumes renewable generation, such as offshore wind. The outcome of this review could have a significant impact on the reinforcement requirements set out within this analysis either increasing or decreasing the requirement for these.

Electricity Networks Strategy Group Sponsored 2020 Grid Study

185. The Electricity Networks Strategy Group (ENSG), a senior industry group jointly chaired by DECC and Ofgem, is developing a 'vision' of the GB electricity network needed to meet the 2020 renewables target and our longer-term energy and climate change goals.

186. The ENSG has asked an industry group (chaired by DECC) to work with the Transmission Companies to develop likely generation capacity deployment scenarios (renewable and conventional) needed to 2020 and beyond and to consider the scale and location of additional transmission capacity, together with costs and associated timescales of investments that would be necessary throughout the GB transmission network to accommodate these scenarios.

187. The first stage of the study considers scenarios to 2020, with a second stage to consider 2025 & 2030 scenarios and is scheduled for completion by April '09. The outputs from the study will be used by the ENSG in developing its vision for the network.

6. Conclusions

188. A range of sites around the coast of Great Britain have been analysed to assess their suitability for connecting offshore wind generation and the impact of connecting at these locations. Given a range of input assumptions around the prevailing generation and demand conditions as well as the design of offshore networks and industry frameworks in place, the reinforcement requirements for the wider interconnected electricity transmission system were also assessed.

189. The analysis found that there are suitable sites available for the connection of up to 25GW of additional offshore wind over and above the 8GW already planned, but that a level of system reinforcement was required in order to facilitate these. Some areas with potential for development did not require a significant level of reinforcement beyond an extension of existing onshore substations against the input assumptions considered. However, it is worth noting that a significant portion of the offshore network is in fact located onshore. Specifically, most offshore developments will have to build a substation large enough to accommodate HVDC converters and/or reactive compensation equipment and transformers in order to connect to the onshore system. The impact of this equipment at the 'onshore interface point' was likely to be greater than that of reinforcing the connection point forming part of the onshore transmission system in the majority of cases.

190. This study has sought to illustrate the onshore impact of connecting offshore wind on an incremental basis, separating out reinforcement requirements driven by general background assumptions, including other generation projects. Undertaking such an investigation and ascertaining this incremental requirement on a complex, interconnected system such as the electricity transmission system is not a straight forward task. With this in mind, and given the input assumptions used, the study found that there is sufficient capacity on the onshore transmission system (arising from closures of conventional plant and the greater sharing of system capacity for wind generation) to accommodate up to 10 GW of the possible 25GW of offshore wind without the need for major system reinforcement (i.e. no requirement for additional overhead line routes). However, some of the additional sensitivity studies undertaken have illustrated that the ability to connect this 10GW may be reduced as a consequence of other generation developments. The regional dispersal of this 10 GW is illustrated in Figure 25, below.

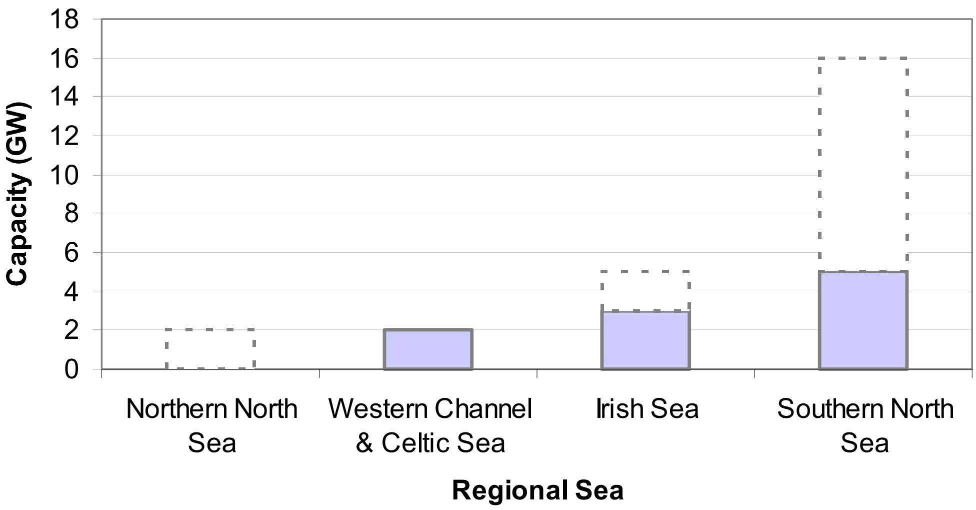


Figure 25 – Installed Offshore Wind Dispersal for 10GW Total

191. Beyond this initial 10GW, development of the Southern North Sea offshore wind resource is assumed to increase beyond a critical point that triggers the need for major wider system

reinforcement along the east coast transmission system. This level of wind capacity is illustrated in Figure 26, below.

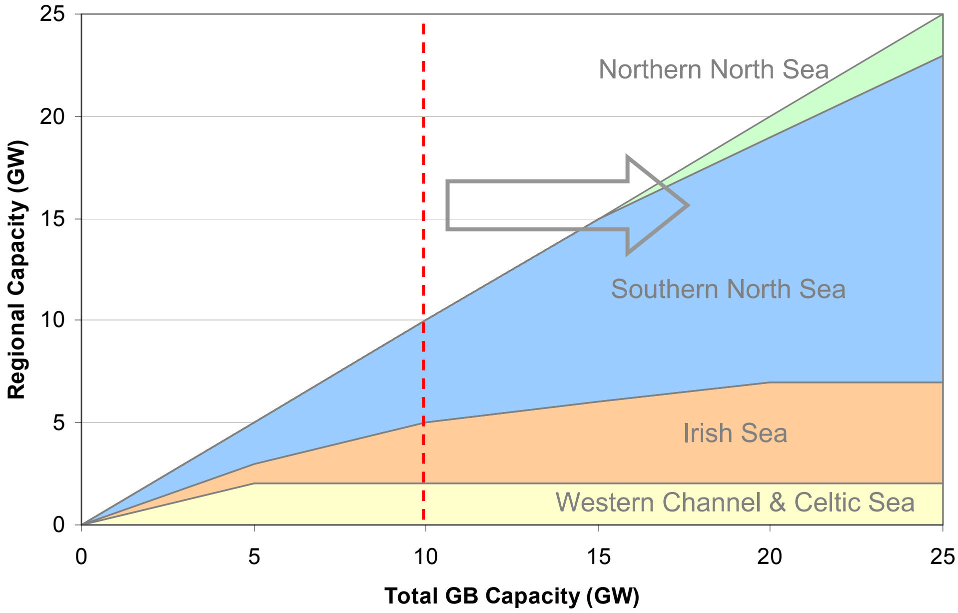


Figure 26 – Location of Wind Development beyond 10GW

192. The potential requirement for new overhead lines begins to materialise in the Yorkshire, Lincolnshire (or Derbyshire), Essex and Suffolk regions when the total volume of offshore wind exceeds 10GW as explained within the 'Results Summary' section, above, on a regional basis. The location of these potential new overhead line routes in England and Wales are shown in the figure, below.

Table 50: Overall Indicative Onshore Transmission Costs for 25GW

	Regional Sea	Local Substation Cost	Major Wider System Reinforcements	Indicative Total
1	Northern North Sea	Currently being assessed through ENSG study		
2	Southern North Sea	£140m	£490m	£630m
3	Eastern Channel	No wind assumed		
4	Western Channel & Celtic Sea	£35m	--	£35m
6	Irish Sea	£55m	£190	£245m
			Indicative Total Onshore Costs	**£910m**

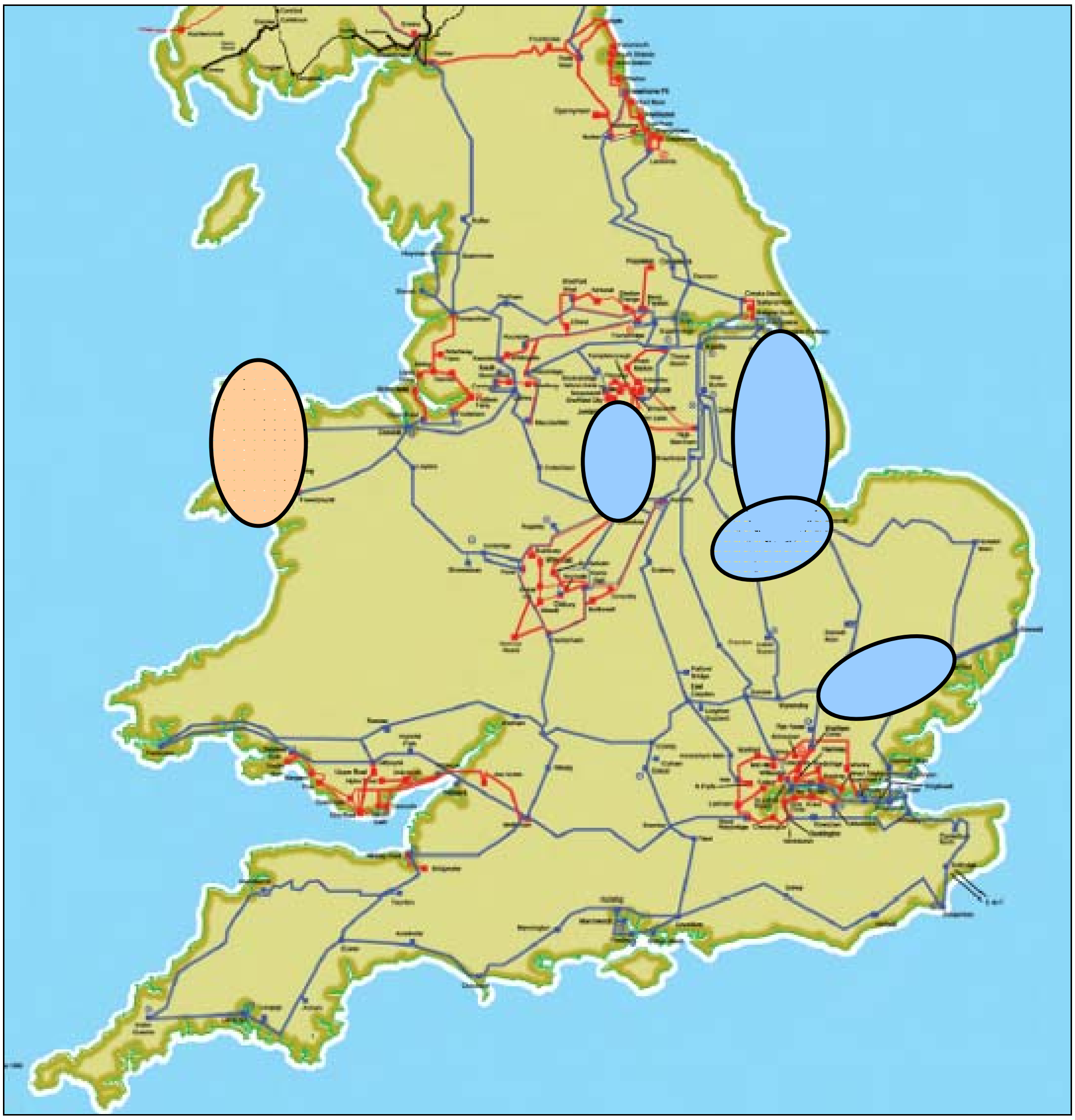


Figure 27 – Location of Potential Major Onshore Reinforcement Requirements

193. Reinforcement requirements identified have been formulated under the assumption that a certain level of coordinated and optimised development takes place in accommodating the total amount of offshore wind generation that could materialise. Indeed, if coordinated development does not occur and projects are considered on a piecemeal basis, the overall network design and substation extension requirements are certain to lead to a sub-optimal solution with a significant increase in the impact on the onshore network.

194. To facilitate such an optimum design, allowing for minimal levels of reinforcement, investment in transmission assets both onshore and offshore may have to take place prior to individual projects materialising. This is different to the current approach of investment only occurring once a generator has a connection agreement with the GB System Operator (National Grid Electricity Transmission) and financial securities are put in place to cover the cost of these investments in the case of project termination.

Appendix 1 – Building Blocks of Electricity Transmission

In simple terms, an electricity transmission system is comprised of connection and/or bussing points, known as ***substations*** and interconnections between these points made from conducting materials known as ***overhead lines*** and/or ***underground cables***. As this system is operated at different voltages depending on the amount of electrical energy to be transmitted, large pieces of equipment called ***transformers*** are also required to change from one level to the next. The majority of electricity in Great Britain is generated and transmitted as alternating current (AC) as this allows for the aforementioned transformation process to take place. However, due to the potential distance from shore, relative size of some of the offshore wind generation projects that could materialise and the limitations of AC cables in this respect, many are expected to come ashore utilising direct current (DC) technology. This configuration would therefore require a further element, known as a ***converter station*** in order to interface with the AC, onshore system. The elements outlined above are explained in some detail, below.

A1.1 Substations

Substations are connection and/or bussing points to the transmission system, and they fulfil a range of functions. A substation is necessary wherever a connection to the electricity transmission system is required for either generation and/or demand as well as at the interface points with other systems. These interfaces normally require the connection to be at a different voltage to the standard 400kV, 275kV and 132kV levels at which the transmission system in the majority of Great Britain operates. This interface between voltage levels is achieved by the installation of ***transformers***, which are explained in greater detail in the following section.

Another function of electricity substations is to act as a bussing point (or marshalling point) to permit the transfer of power between circuits as well as providing a point of connection for various pieces of 'compensation' equipment that maintains the quality of this power. In addition, the day to day operation of an electricity system requires the ability to switch in and out components of such a system in order to undertake maintenance and repairs or simply to redirect the flow of power across circuits. These various functions are achieved through the installation of switchgear (disconnectors and circuit breakers), busbars (large solid conductors connecting several circuits) and reactive compensation equipment (capacitive and inductive devices that maintain power quality within statutory levels). Most substations achieve a range of these functions in a single location.

As highlighted above, the large pieces of equipment located at substations include ***switchgear***, ***busbars***, ***transformers***, and ***reactive compensation*** equipment, which are discussed below and illustrated in Figure A1-1. Substations also contain supporting equipment such as back-up power supplies, relays and logic systems for the monitoring and protection of components on the system as well as meters which measure the flow of power into and out of the transmission system to name but a few. These supportive elements, operate at lower voltage levels, are housed within substation buildings and as such have a minimal visual impact, so are not discussed further.

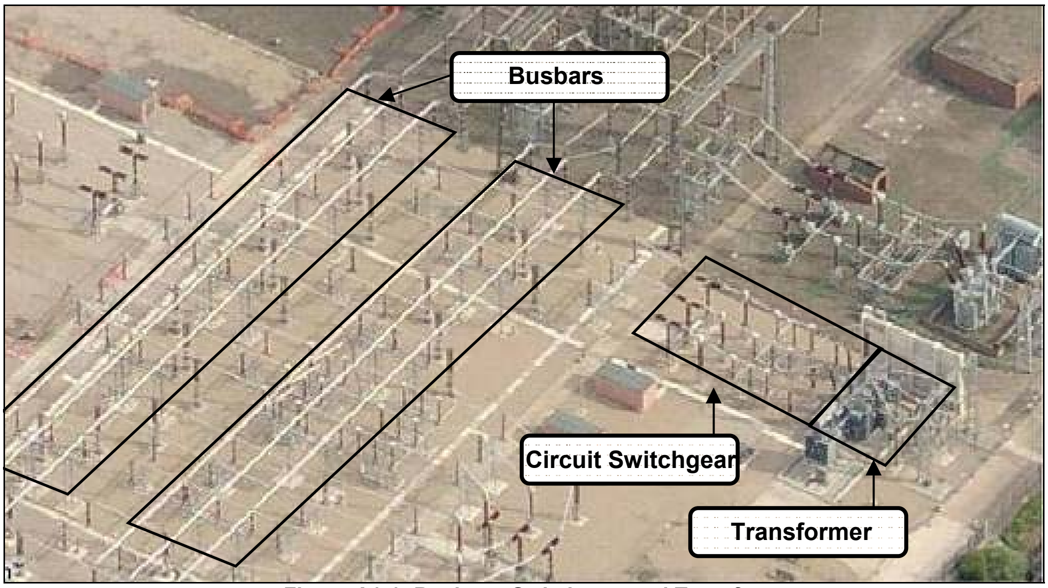


Figure A1-1: Busbars, Switchgear and Transformers

Switchgear includes equipment that allows circuits to be switched in and out through the use of circuit breakers. These circuit breakers perform the same function as those in a domestic installation, but operating at transmission voltages. In addition, disconnectors, when open, form a mechanically operated means of physically isolating sections of equipment that, together with earthing switches, ensure that these can be worked on in safety with the remaining installation at operating voltages. Disconnectors can also be used to enable individual circuits to be connected to a variety of points on the system.

Busbars is the term given to the common connection that a range of circuits are connected to within a substation, permitting the flow of electricity between them. They are tall, rigid structures as illustrated in Figure A1-1, above.

There are two fundamental designs of switchgear that can be employed. The type of busbars at a given installation will also, generally, match the design of the switchgear.

Air Insulated Switchgear (AIS)

This is the predominant type of arrangement in use on the transmission system within Great Britain. As its name implies this technology is comprised of discrete components that achieve their insulation (electrical separation) by their physical separation in air. These components are supported on porcelain insulators that are mounted on steel or concrete structures. An AIS substation requires a relatively large land area, and is approximately 12m high at 400kV. A 400kV ‘bay’ consists of a conductor, disconnectors and a circuit breaker as shown in Figure A1-5. A 400kV ‘bay’ provides the necessary equipment required for connection of a single circuit and occupies an area of approximately 21m by 40m, excluding the busbars. A typical substation will comprise of anywhere from 6 to 15 of these ‘bays’ as well as buildings containing supporting equipment, access roads, site facilities and some form of screening (the use of vegetation to minimise visual impact).

A substation that is air insulated is generally the most economic design to employ and is therefore used where possible. Figure A1-2, below, shows an aerial view of a typical AIS substation.

Figure A1-2: Aerial view of typical outdoor, AIS substation

Gas Insulated Switchgear (GIS)

In the design of gas insulated switchgear, the individual switchgear components are contained in steel or aluminium housings that are filled with pressurised Sulphur Hexafluoride (SF_6) gas. The SF_6 gas provides an improved level of insulation to air due to its much higher dielectric strength. It is for this reason that less space is required between 'live' elements of electrical equipment and consequently that overall GIS substations require far less land area. In general a GIS substation has its switchgear contained in a clad building that is similar to an industrial unit, and can be about 10m high. A 400kV, GIS bay is approximately 4m by 7m (one 30th the size of AIS), excluding busbars. The number of bays that are required and the indoor space for supporting equipment are the same as that of a typical AIS substation.

GIS substations generally come at a higher cost than AIS even though as highlighted above, require much less land area. This is clearly illustrated in Figure A1-3, which shows an aerial view of a typical indoor GIS substation and Figure A1-4 shows an indoor GIS circuit breaker. In line with obligations to plan an economic and efficient system, onshore transmission owners generally only propose GIS installations close to the coast (within ~5km), where salt spray pollution can cause operational problems, where high levels of pollution exist and/or land availability is constrained. SF_6 is also a potent green house gas if released into the atmosphere and is therefore monitored and controlled closely.

Figure A1-3: Aerial view of typical indoor, GIS substation

u

Figure A1-4: Indoor GIS circuit breaker

Indoor Substations

Prior to the development of GIS, where substations were required in polluted areas, the approach was to construct large buildings around AIS equipment. This resulted in extremely large buildings approaching 20 metres in height. There are a number of these installations currently in existence on the transmission system. Where extensions are proposed to this type of design, one option is to undertake this extension using GIS, in order to minimise the amount of building extension required. Figure A1-5, below, illustrates the relatively large size of such indoor AIS substations and Figure A1-6 shows an indoor 275kV circuit breaker.

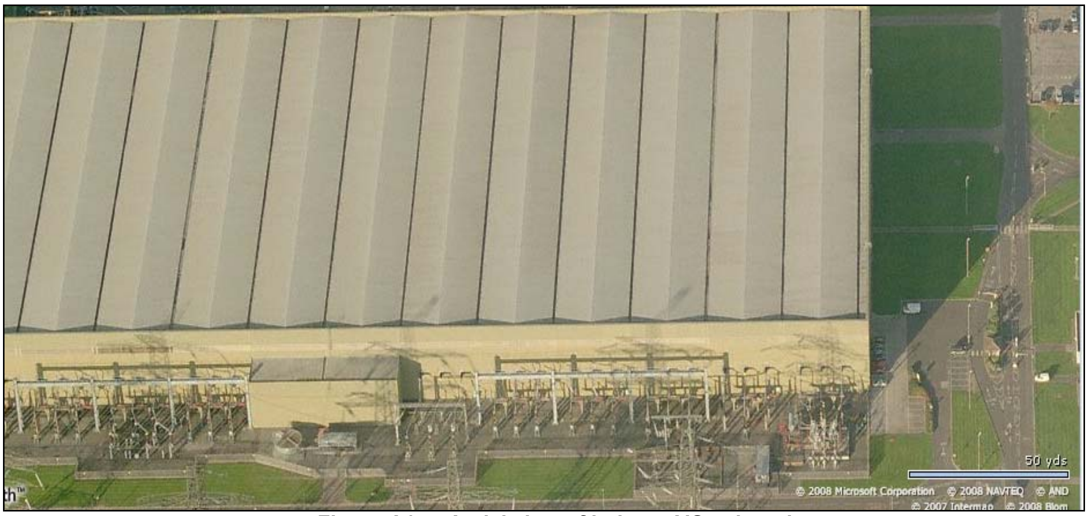


Figure A1-5: Aerial view of indoor, AIS substation

Figure A1-6: Indoor 275kV AIS circuit breaker

Substation Configurations

In addition to the types of switchgear employed, there are a range of 'configurations' used at electricity transmission substations in Great Britain. The configuration is the manner by which the switchgear is arranged and the circuits are connected. Due to a range of factors including physical space constraints, the historic cost of circuit breakers, and changing security standards (i.e. GB Security and Quality of Supply Standards, GB SQSS), not all substations follow the same layout and arrangement. The two fundamental configurations that have generally been employed in Great Britain are the 'mesh' substation and 'double busbar' substation design. The difference in these is illustrated by simple, single line diagram, below.

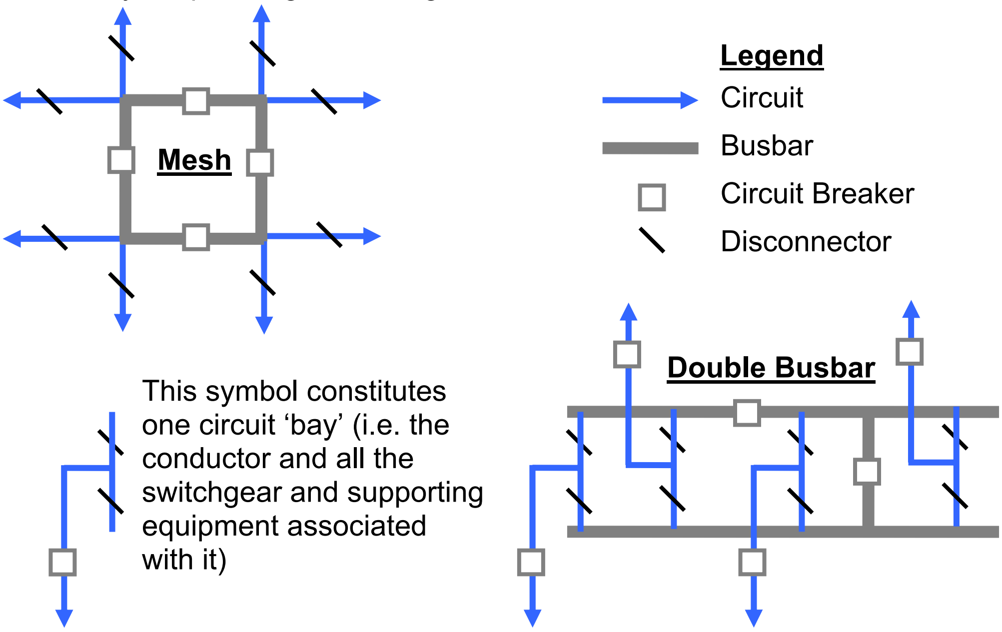


Figure A1-7: Mesh and Double Busbar Configurations

In following the design criteria laid out in the GB SQSS, double busbar configurations are necessary for connections of generation to the onshore transmission system. The benefit of this design is that each circuit has its own circuit breaker and that less of the system is taken out of service for a given fault or maintenance outage (i.e. the system is generally more robust with this design).

Extending Existing Substations

Where the connection of offshore wind generation is proposed to existing substations, the first consideration is to examine if the substation configuration is that of a double busbar (as illustrated in Figure A1-7), and if not, if it is possible to reconfigure the site to achieve this.

For the offshore wind generation connections the majority of locations will require the creation of at least two additional circuit bays, which will allow for a range of connection capacities (as highlighted in the offshore connection design section, below). For reasons of resilience, these two new circuit bay extensions would be located on different sections of busbar (i.e. separated by a circuit breaker) and normally at opposite ends of an existing site. This is illustrated in Figure A1-8, below. The size and therefore visual impact of a standard one bay extension is as described above for AIS and GIS.

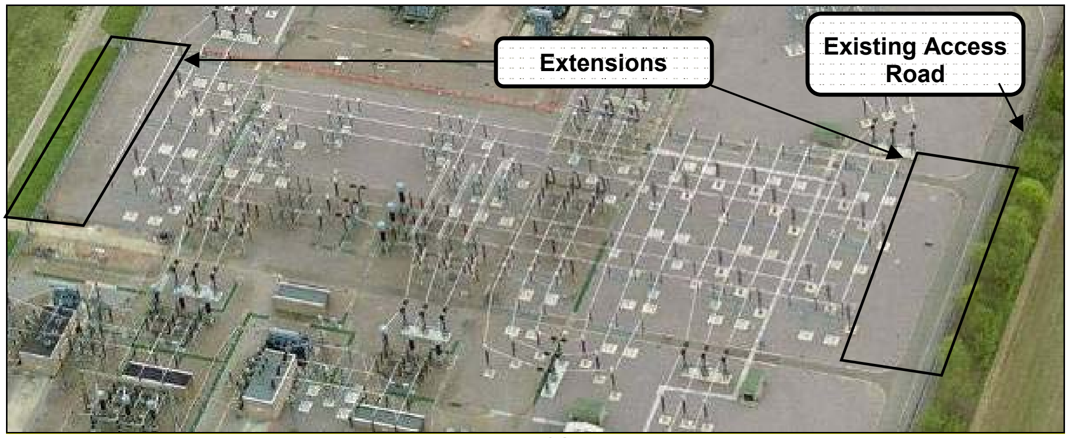


Figure A1-8: Location of Substation Extensions

For the vast majority of existing substations, spare circuits do not already exist, and therefore busbar extensions will be required at each end of the substation to facilitate connection with the offshore transmission system.

As part of this study, additional circuit connections and any changes to substation configurations will have been accounted for at each individual substation.

Around a 400kV substation site, there is a road route to provide a means of getting access for vehicles to facilitate the delivery of materials, cranes for maintenance and replacement amongst other functions. This road has to maintain a sufficient distance from the 'live' electrical equipment in order to allow access without the need to interrupt electricity supply. The overall site is then surrounded by a palisade fence to secure the site. The palisade fence requires a minimum horizontal clearance of 4.6m to 6.6m from the nearest 400kV equipment to maintain safety clearances.

In order to maintain the potential for further extending the substation easily in the future, it is best practice to ensure that any new developments do not preclude the expansion of the busbars along their existing orientation. This may limit the areas available for the positioning of new equipment forming part of the interface between onshore and offshore transmission systems.

An individual 400kV circuit occupies a width of approximately 20 metres. In addition and as mentioned above, to permit construction whist existing equipment remains 'live' and in-service, there may be a need to provide additional separation with the neighbouring bays in the design. The picture in Figure A1-8, above, indicates the approximate additional width required to accommodate an extra circuit at each end of the substation. It is clear that in this example there is a need to extend the site into the adjacent field as well as modify the existing road layouts. Here, this will require the purchase of additional land, and lead to the need to obtain planning permission for the extension that will have an impact on the construction programme. The termination and interface equipment forming part of the offshore transmission system will occupy additional land to that described so far. This will normally be located adjacent to the existing substation in order to minimise the cabling required. It is necessary to evaluate each site individually to identify the exact requirements and local issues. This is done for the selected sites in the 'Results Summary' section.

Where shared ownership of assets exist on a site, for example with a distribution network operator (DNO), there also needs to be a detailed consideration of the needs of the independent owners with regard to arrangements for site access, safety rules, security issues, pollution control, external services, maintenance and emergency repairs. These will be the main factors in the final design arrangements, fence lines, roads and building locations which will have an impact on the overall site area and arrangements. These issues hinder the ability to accurately identify adequate land requirements and provide an overall description and assessment of the development where planning permission is required.

To achieve the necessary extensions a substation site is examined to identify if sufficient space is available within the existing fence line and land ownership to construct the new assets. Without design details being available from the offshore transmission owners, it may not be possible to undertake a full design co-ordination exercise to identify the overall site extension requirements and impacts. The basic requirements of an AC or DC connection can, and have been, assumed for this study. However, the actual requirements may be significantly different to this once a competitive tender process for an offshore transmission owner and a detailed design/cost benefit analysis exercise has been undertaken.

New Substations

Where new substations are proposed these will be of double busbar design and the selection of AIS or GIS will be in line with the guidelines outlined above.

In addition to the circuit bays (illustrated in Figure A1-7) required for the interface with the offshore transmission system, further circuit bays will be required for the connection of new ***overhead line*** circuits at some sites. The overall size of the substation will depend on the capacity of the individual overhead line circuits and the total offshore wind generation capacity connected. As previously highlighted, a typical installation will have anywhere from 6 to 15 bays in total.

Outdoor substation surface areas are covered with stone chippings laid on site fill material. Non-permeable surfaces are limited to the roads, equipment foundations, and building areas. As such substations do not create the rain run-off and drainage problems that arise with large paved or concreted areas.

It is proposed that several new substations on the onshore transmission system are established to either connect the offshore wind generation, or as part of resulting wider infrastructure development. In these instances detailed studies and surveys will be undertaken to identify appropriate locations, layouts and mitigation proposals such as tree screening and hard landscaping. This study has aimed to arrive at an overall location which balanced the technical needs of the transmission system with the overall environmental impact of the substation and associated ***overhead line*** connections. The outcome of such a study would formulate part of an application for planning permission. Access roads and routes suitable for the delivery of ***transformers*** (discussed further in the following section) will also need to be considered. Land purchase and planning permission will be required.

The issues relating to the interaction with the offshore transmission owner, as described above for extending existing substations, apply equally to new substations and raise a potential problem in being able to present a comprehensive design and impact assessment when seeking planning permission.

A1.2 Transformers

The economic voltage level of connection equipment for a given offshore wind generation project is directly related to the amount of electrical power that is being transferred across the offshore transmission system. As explained in the ''Onshore/Offshore Transmission System Interface" below and "Results Summary" section of the main report, the majority of projects are expected to connect via a submarine and underground cable system which is 132kV or 245kV for AC and 300kV for DC into a 400kV substation onshore. Hence, in order to interface these different voltage levels, transformers will be required at the onshore interface point.

Transformers are large steel tanks that contain a magnetic core and copper windings wrapped around the magnetic core, that allow for a change in voltage level. The core and windings are immersed in a mineral oil that provides insulation and also acts as a means of cooling. The cooling is achieved by circulating the oil through external radiators, and this may be enhanced by the addition of fans and/or pumps. A header tank maintains the level of oil in a transformer and caters for the expansion and reduction in oil volume as loads increase or decrease, and the temperature of the windings and oil vary.

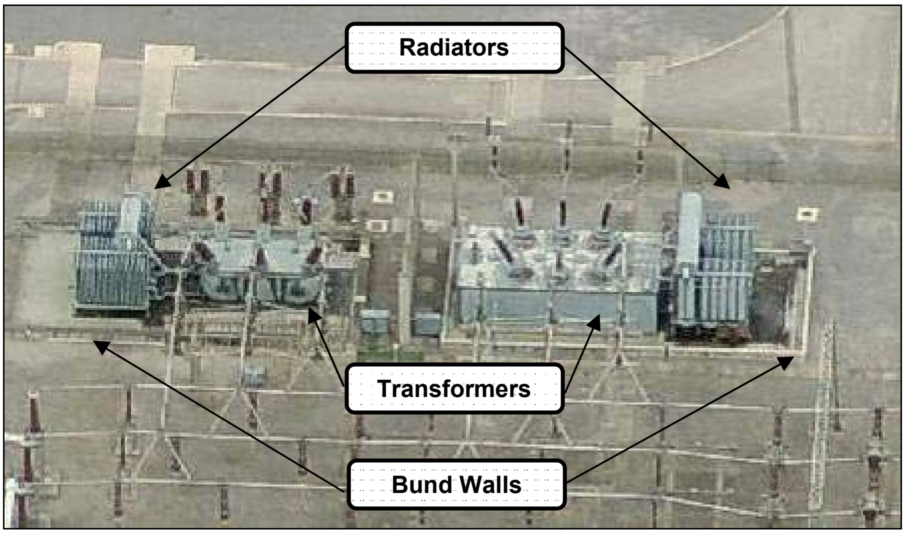


Figure A1-9: Typical 1100MVA Transformer Installation

To prevent any oil leakage causing pollution, transformers and their radiators, illustrated in Figure A1-9, are contained within a bund wall. The drainage of this is routed via oil interceptors, before being discharged via the oil interception system. The road local to the transformers where oil tankers and specialist equipment used for oil filtration and processing can be positioned, are also surrounded by bund walls and their drainage routed via the oil interception system. A typical 1100MVA transformer contains approximately 130,000 litres of oil.

As transformers contain large quantities of oil there is a small risk that, should an internal fault arise, quantities of gas could be created as the oil is exposed to elevated heat energy during the fault. In some rare instances this can lead to failure of the steel tank and the outbreak of an oil fire. To guard against such an event that could lead to cascading failures of adjoining equipment, large fire barrier walls or other form of segregation measure may be required. Protection of the public and other third parties from the effects of any such event also needs to be considered in the overall layout and site arrangement.

Due to the size and weight of transformers they are classed as 'abnormal' loads and require their transport routes to be examined to ensure that the roads, bridges and other crossings along the route are adequate to accommodate their weight and size. Agreement from the Highways Agency is mandatory for the proposed route. The transport weight of an 1100MVA transformer is around 150 Tonnes. The site access and roads need to be able to permit the specialist, low-loading vehicle to manoeuvre the transformer to off-loading locations. This results in wide turning circle areas that need to be free from obstructions. This and the need for shallow road gradients influence the site and surrounding landscaping arrangements. It is best practice to avoid road transportation and utilise water-born transport as far as possible. This requires surveys to identify suitable routes and landing areas, and can lead to costs in establishing quays alongside rivers as well as routes from these to the substation locations.

Figure A1-10: Delivery of an 1100MVA Transformer to Site

Transformers are the main source of noise in a substation due to their magnetic circuit which produces the audible 'hum' often emanating from electricity substations. The overall noise level can increase where cooling fans are also present. Noise surveys will be required and where necessary noise enclosures fitted around the transformers to reduce the noise levels encountered in the vicinity. Figure A1-11, below, illustrates a transformer being installed within a noise enclosure that will eventually be covered with a roof. It also provides a sense of scale against the person in the green mobile elevated work platform.

Figure A1-11: Typical Transformer being Installed within a Noise Enclosure

A1.3 Reactive Compensation

Alternating currents and voltages in an electrical system give rise to alternating transfers of electromagnetic and electrostatic energy between elements of the transmission network and between the transmission network, generators and loads. These energy transfers are known as 'reactive power', which flows around the system in combination with the 'real' power – as measured in MW – that the network transmits from generators to demands. Excessive reactive power flows in the system can result in unacceptable voltages, excessive losses, or both, so reactive power is carefully managed. To this end, transmission owners will install ***reactive compensation*** equipment, of one of two types – capacitive or inductive – to maintain the local balance of reactive power.

In the context of offshore wind generation, reactive compensation of the inductive type is likely to be required at or near the connection point of offshore AC cables. The capacitive type of compensation is likely to be needed at the connection points of HVDC converters that use 'current source' (CSC) technology. However, with currently available and foreseeable technology, offshore HVDC connections from wind are most likely to use the 'voltage-source' converter technology, or VSC (explained further below), which needs no external reactive compensation.

An inductive compensator, otherwise known as a shunt inductor or shunt reactor, consists of a coil of wire contained in an oil-filled steel tank. It is therefore physically similar to a transformer and has much the same space requirements and environmental impact (see Figure A1-12). It would have to be connected near the terminals of the offshore AC cables.

Figure A1-12: Inductive Reactive Compensator

A capacitive compensator, if required, would consist of multiple capacitor units mounted in open-air insulated frameworks. The footprint would typically be from several tens of square metres up to more than 100 square metres, but the exact size would be application-specific (see Figure A1-13).

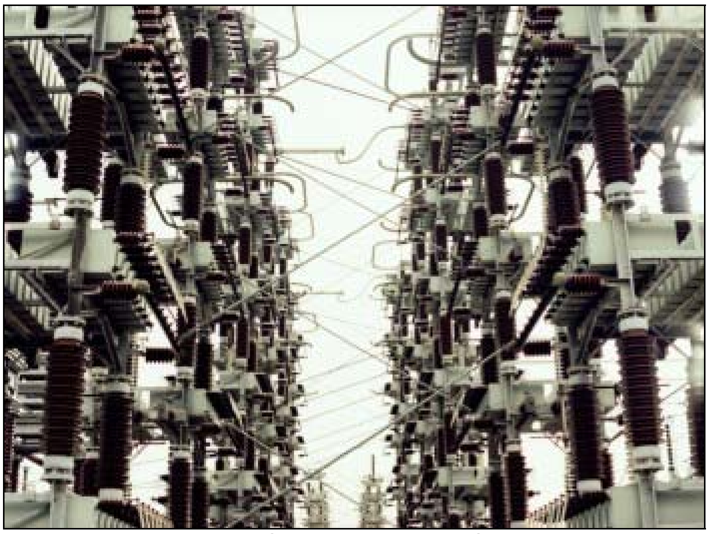


Figure A1-13: A Capacitive Reactive Compensator

A1.4 Onshore/Offshore Transmission System Interface

<u>AC Connections</u>

To accommodate new offshore wind farm connections operating at a voltage of 132kV or above, the design of the offshore transmission system will need to comply with the offshore section of the GB SQSS, as highlighted in the introduction section of the main report. In order to assess the impact of connecting offshore wind generation to the onshore transmission system, this offshore design must be investigated.

The GB SQSS for offshore requires that a minimum of two ***transformers*** with a capacity of at least 50% that of the installed output capacity of the wind farm are installed for all future offshore wind projects (given their size).

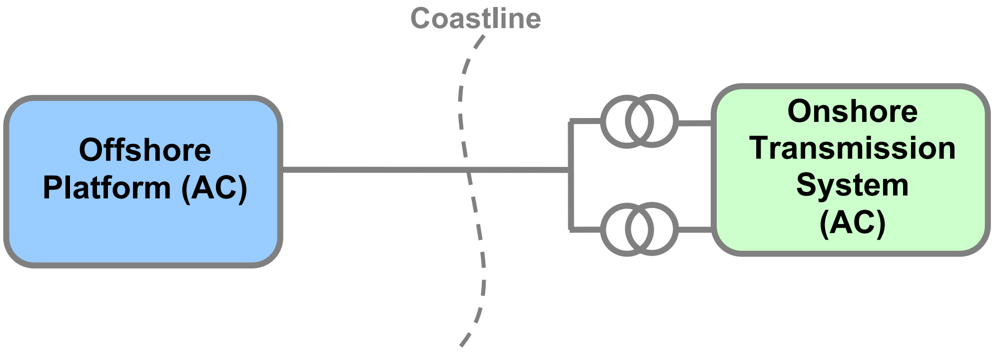


Figure A1-14: Assumed Standard AC Onshore Interface

Hence for a single offshore connection it has been assumed that two 400kV circuit bays will be required, at the onshore connection substation, as illustrated in Figure A1-14.

The offshore transmission owner will require land area for the ***underground cable*** termination, ***transformers*** and any ***reactive compensation*** equipment. These components will most likely be located outside of the substation boundary fence of the onshore transmission owner, and also include buildings for control and communication equipment and access roads within an independently fenced area. An example of such a substation for the AC connection of a Round 1 offshore wind project (at 132kV and therefore without the requirement for transformers) is shown in Figure A1-15, below.

Figure A1-15: Round 1 Offshore Wind Generation 132kV Cable Termination Compound (no transformers required)

The onshore substation where the offshore transmission system will interface with the onshore transmission system will require the extension of its busbars for the two new connections as described in the 'Substations' section, above. It is likely that the offshore transmission owner will be responsible for the 400kV circuit switchgear and transformers connecting to these busbar extensions. These works will normally be accommodated within the boundary of the 400kV substation belonging to the onshore transmission owner.

Where two AC connections are proposed to one onshore substation, it is possible that the offshore system design could utilise 'shared' transformers between the two projects and remain compliant with the GB SQSS. This is illustrated in Figure A1-16, below. In undertaking this study it has been assumed that this type of strategic approach to optimising the number of assets required will take place. However, this would require a certain level of coordination amongst all stakeholders.

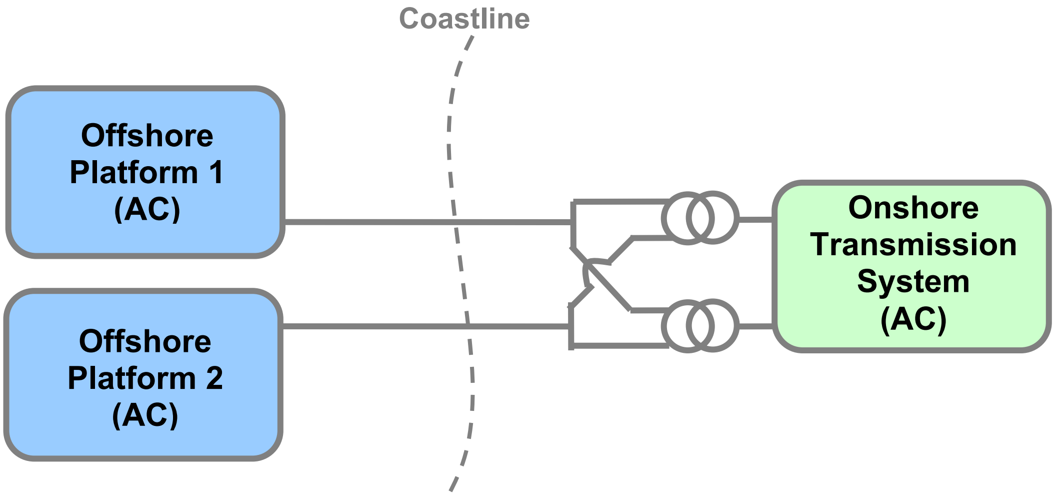


Figure A1-16: Assumed Sharing of Assets forming part of the Offshore Transmission System

Although the extent of the equipment forming part of the offshore transmission system will increase for two connections, the number of 400kV circuit bays required could remain as two. The required design at each site will be subject to individual economic assessment to arrive at the desired overall design.

DC Connections

Where DC connections are proposed, the DC converter and its associated transformer will create a single connection system, leading to a single 400kV switching bay requirement at the onshore interface point for each connection. This is illustrated in Figure A1-17, below. DC, as opposed to AC, connections are likely to be required where offshore wind generation projects are located a significant distance from the shore at which the limitations of AC cables become apparent.

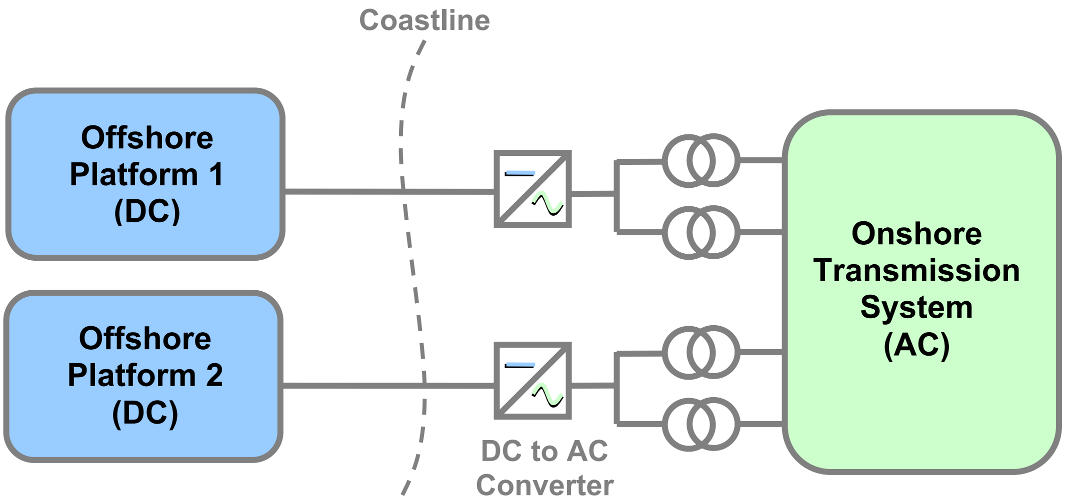


Figure A1-17: Assumed Standard DC Onshore Interface

Two forms of technology exist for high voltage direct current (HVDC) connections. Both Current Source Converter (CSC) and Voltage Source Converter (VSC) technology is available at a trade off between cost, losses, flexibility and land requirements. At this stage, it appears that the more flexible VSC technology will be most economically suited to offshore HVDC connections. These require less land area, as they do not require the same level of AC filtering equipment to be installed in order to maintain power quality as that required for CSC designs typically used for point-to-point interconnections (such as the Great Britain link with France).

The land area required for a VSC-HVDC converter termination is expected to be significantly greater than that of an AC connection. Indicative dimensions provided by the equipment suppliers are that a single 1000MVA VSC-HVDC installation will occupy up to 125m x 95m. The height of the building housing these converters is approximately 24m. Additional land for access roads as well as areas for site screening and landscaping will also need to be accommodated.

The HVDC converter equipment generates a level of noise that will need to be attenuated through the building design. Ancillary equipment such as cooling systems are required, so these will also need to be considered. However, these issues should be addressed in the standard designs supplied by equipment manufacturers.

Indicative dimensions of a 1000MW ABB, VSC-HVDC installation are shown in Figure A1-18, below.

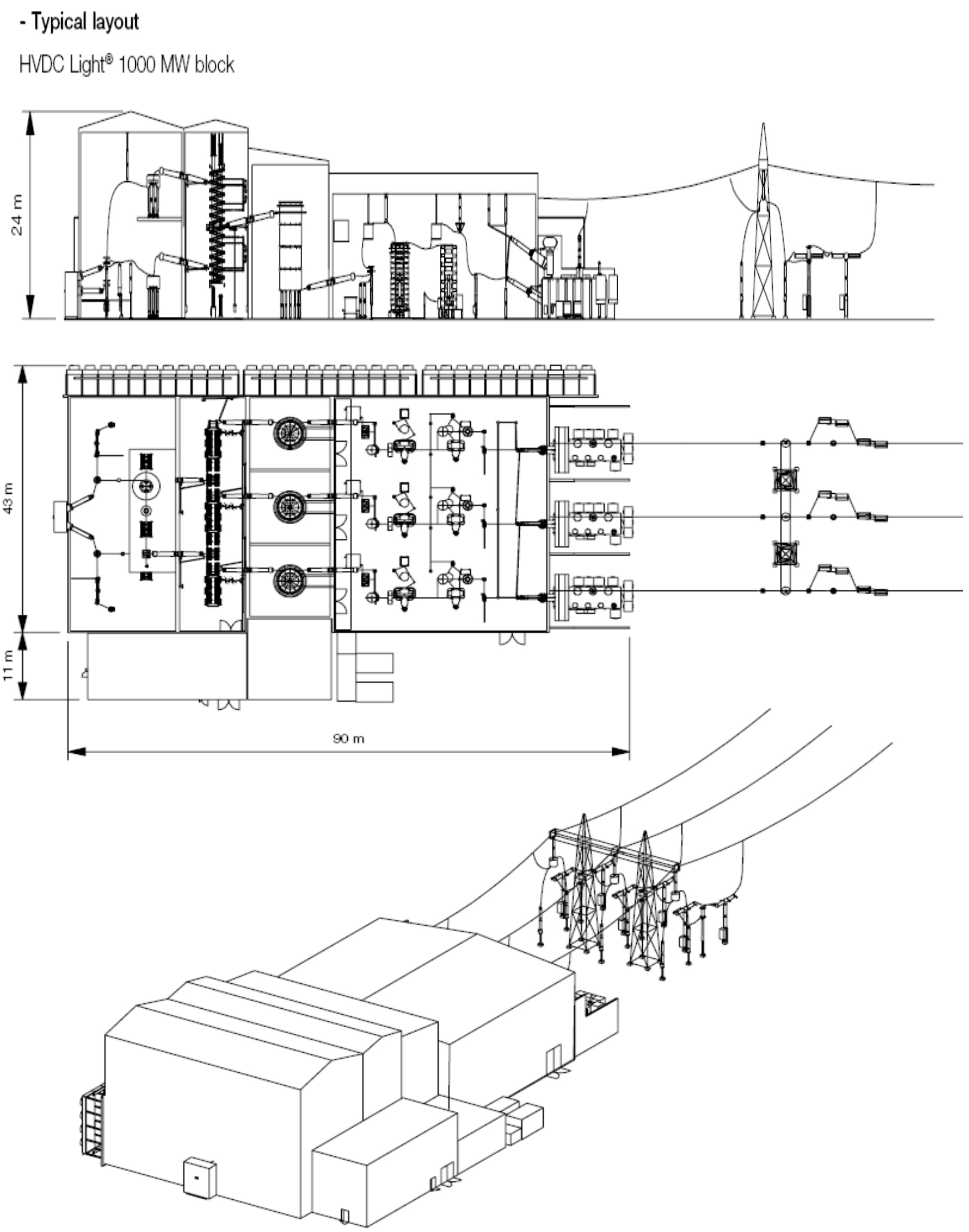


Figure A1-18: Indicative dimensions of a Voltage Source Converter (VSC) High Voltage Direct Current (HVDC) Converter Station (Example: HVDC Light © ABB)

It is clear that where HVDC connections are proposed, the installation of HVDC converter stations onshore will be a dominant feature of the land based works. Indeed, the potential connection solutions utilised to gauge the onshore impact of offshore wind generation, indicate that 2 or 3 of the above converters could materialise at one site.

A1.5 Cables and Cable Routes

With currently available and foreseen technology, offshore wind generation projects will be connected to shore by submarine cables. For AC connections, the most economic design is a 3-core cable where all 3 phases of a circuit are contained within a common oversheath (i.e. wrapper). For DC connections 2 separate cable cores (possibly three depending upon overall designs) are required that will be laid together. Most submarine cables will need to be buried in the sea bed to avoid damage from marine activity.

Onshore there is a need for a transition joint bay where the submarine cable is connected to the underground cables. For some AC designs, the underground cables could be 3 separate cables, laid together in a trench. This is illustrated in Figure A1-19 and Figure A1-20, below. The exact arrangement will be specific to the circuit, its rating and the thermal performance of the ground characteristics in which these are laid. This will be an economic balance between the amount of copper or aluminium in each cable and the cost of the excavation/installation. A similar situation will exist for the DC cables however there are normally only 2 cables in this instance.

Figure A1-19: Underground Cable Joint Trench

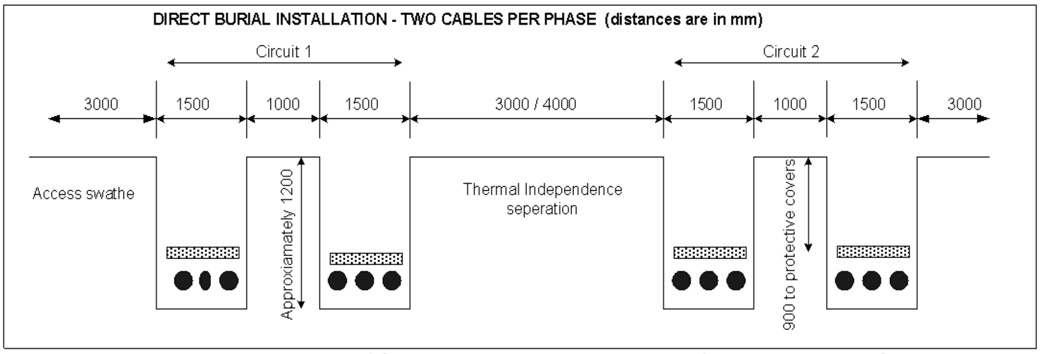


Figure A1-20: Example of Separation Distances Required for Underground Cable

Along the onshore, underground cable routes, cable joints will be required at intervals of around 800 to 1000m depending on the size of the cable. Joint bays will need to be established at these locations that will take up a greater width than the normal cable trench. Route surveys will have to be undertaken to determine the most appropriate locations for these. For the AC cables these may be accompanied by the need to install kiosks, above ground or at the surface to accommodate cross-bonding and cable sheath connections. This is to ensure the induced currents that arise in cable sheaths are balanced for the entire length of the cable.

Where more than a single connection from a wind farm is required, or where multiple wind farms are to connect to the same substation, separate routes will be necessary for each connection. There are two main reasons for this requirement:

1. Cables generate heat which has to be dissipated through the surrounding ground. Each cable circuit will need to be capable of achieving its current carrying capability (current or thermal rating) independently. Therefore, sufficient separation has to be provided to ensure the heat from one circuit does not affect another. This is normally achieved by separation of 3 to 4 meters between circuits.

2. Resilience is also a consideration which leads to separate routes some distance apart to avoid damage to multiple circuits from any potential disturbance activity such as excavations.

These cable routes will have to be identified and agreements reached with any land owners. If public highways are to be used for the cable routes then access will be subject to the Traffic Management Act.

The land occupied by cable routes will have restricted use following their installation. This is due to the need to be able to access any portion of the route should repair be required, and to ensure current ratings are maintained. Building above the cables, earth mounding and/or stripping and excavation along the easement strip is restricted. The planting of trees and hedges over the cables or within close proximity is also restricted. Where cables are installed in fields subject to agricultural use, there are restrictions on the use of deep cultivation equipment to avoid the risk of disturbance.

Routing cables through open land requires an evaluation of the environment along the complete route. The normal requirement is for an open trench to lay the cables into. Where this runs through the countryside it is necessary to strip and store the topsoil, remove hedgerows or other obstructions, and create access routes or temporary roads for the installation process. The impact of field drainage and drainage of the installation also needs to be addressed in the overall design and programme.

In terms of site delivery, cables are delivered on drums (illustrated in Figure A1-21, below) and their location and handling requires the use of cranes. The areas located for storage have to be prepared and the surface sufficient to support the loads imposed. Access routes and delivery methods and accompanying constraints all form part of the overall route assessment.

Figure A1-21: Cable Drum

In addition, during construction the route identified will have to facilitate not just the width of the cable trench and cable drum storage locations, but also an 'access swathe' area for cable laying machinery and storage of soil taken from the ground. An example of the relative size of this area is shown in Figure A1-22.

Figure A1-22: Access Swathe for Underground Cable Installation

Directional drilling or thrust boring techniques are employed to avoid disturbing sensitive areas, or to cross busy roadways. This itself requires the management of the drill locations and is not 100% accurate.

A1.6 Overhead Lines

In addition to the work required in order to connect offshore wind generation to the onshore transmission system, onshore transmission owners may require additional 400kV system infrastructure to accommodate the changes in power flows on the system across congested areas. This additional capacity across congested areas is normally in the form of reconductoring (upgrading conductors on existing overhead line routes) or where this is not possible, new ***overhead line*** routes. In deciding on a particular reinforcement to relieve a congested area of the system, there are several categories of overhead line conductors to choose from depending on the capacity required and characteristics of the route.

Main features of a Transmission Line

The onshore transmission system uses a variety of tower designs for the support of overhead line conductors which transmit high voltage electricity around the country.

The electricity system until the late 1950s consisted of a series of overhead lines at a voltage of up to 132kV. As demand grew, a system of 275kV lines was developed to feed the major conurbations. This system was further developed and uprated to 400kV in the 1960s. A 400kV line carries about three times as much power as a 275kV line, and about 18 times that of a 132kV line, depending on the precise line designs. At the time of privatisation in the 1990s, the electricity transmission assets were primarily split according to voltage level, hence local distribution companies generally own and operate lines with a voltage of 132kV and below. Most future new, transmission circuits will be designed to operate at 400kV.

Figure A1-23 shows L2, L6 and L12 double circuit towers which are those most widely in use for high voltage onshore transmission in England and Wales. The L2, a typical transmission tower from the 1950s, carried steel-reinforced aluminium conductors in pairs from each insulator[20]. When quadruple conductors were introduced in the 1960s, larger and more substantial towers were needed and the L6 designs were then introduced. The development of lighter all aluminium alloy conductors allowed the smaller L12 design to be brought into use in the 1980s.

The size, height and spacing of towers are determined by the type of conductor required, safety, topographical, operational and environmental considerations. The ability to reconductor an existing overhead line route is limited by the types of towers and overall profile of the route.

[20] Note: A single circuit requires 3 conductors, as electricity is generated and transmitted as 3-phase

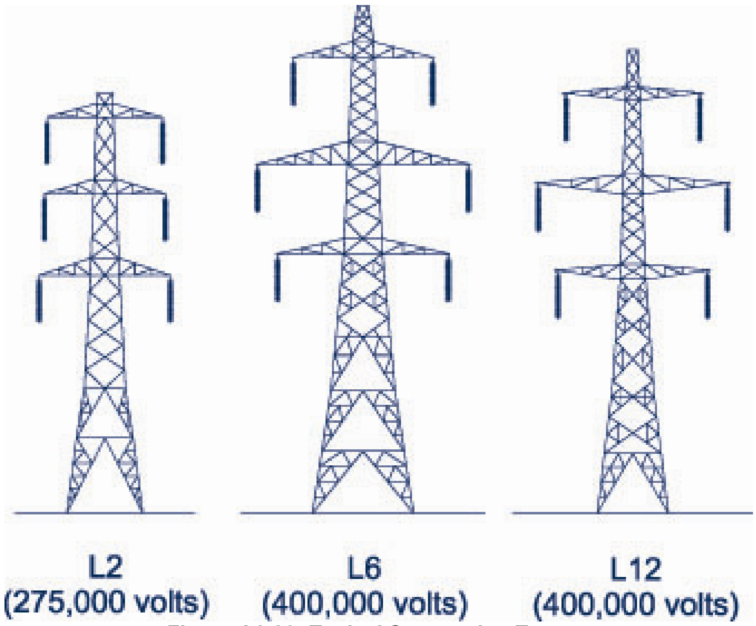


Figure A1-23: Typical Suspension Towers

A typical onshore overhead line route will involve the use of three main types of tower. They are as follows:-

Suspension towers: These support the conductor on straight stretches of line. Conductors are suspended by a vertical insulator string.

Deviation towers: These occur at points where the route changes direction. Conductors are attached by horizontal insulator strings.

Terminal towers: These towers are of greater bulk in order to ensure stability. They occur at the end of overhead lines where they connect with substations or underground cables.

Figure A1-24, below, illustrates the differences in these types for the L12 tower.

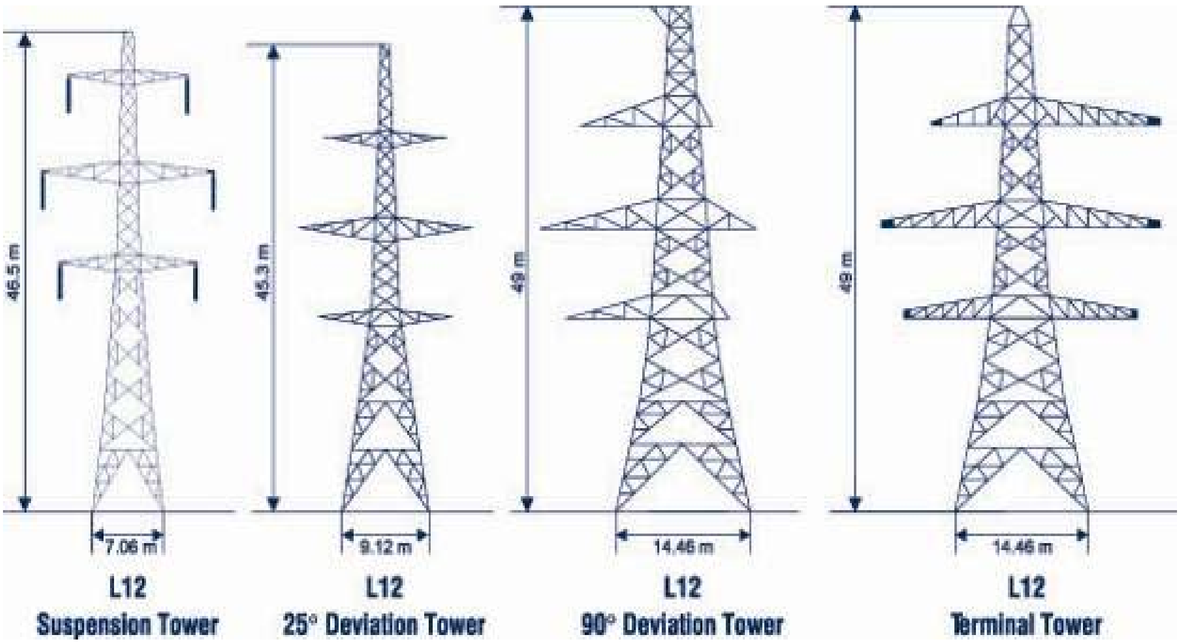


Figure A1-24: Typical Towers in a 400kV Route (L12 example)

Figures A1-25 and A1-26 show the relative visual impact of terminal towers compared to other substation infrastructure.

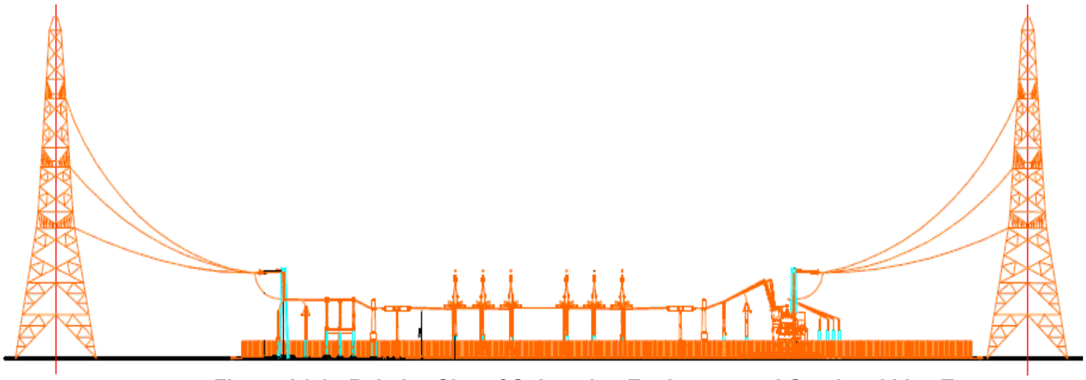


Figure A1-25 Relative Size of Substation Equipment and Overhead Line Towers

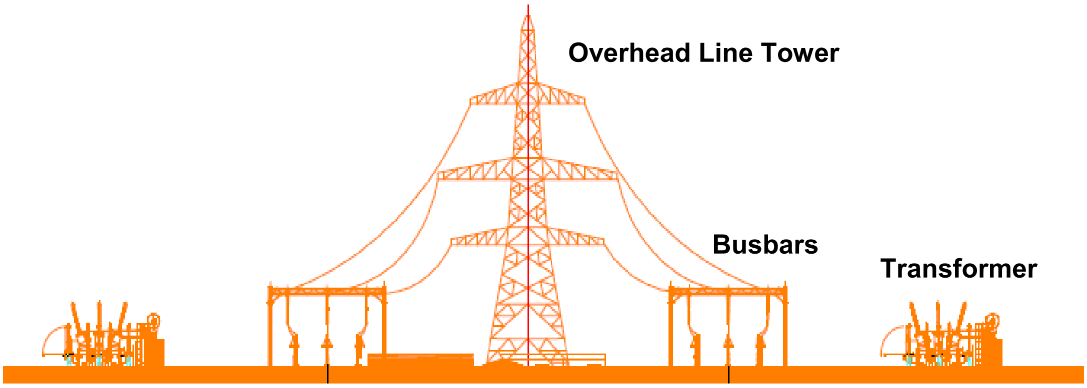


Figure A1-26 Relative Size of Substation Equipment and Overhead Line Towers

The various components of an overhead line route are illustrated in Figure A1-27, below. This illustrates that the conductors strung from towers are bare conductors and utilise the surrounding air as insulation. However, to maintain electrical separation between the conductor and the tower, insulators made of glass or porcelain are needed and hang down from the steel tower cross arms. Most overhead line routes in Great Britain are ‘double circuit’ routes, meaning that there are 2 electrical circuits carried on one tower. Each circuit requires three conductors, which is why a standard double circuit tower will carry 6 conductor sets, and an earth wire on the top.

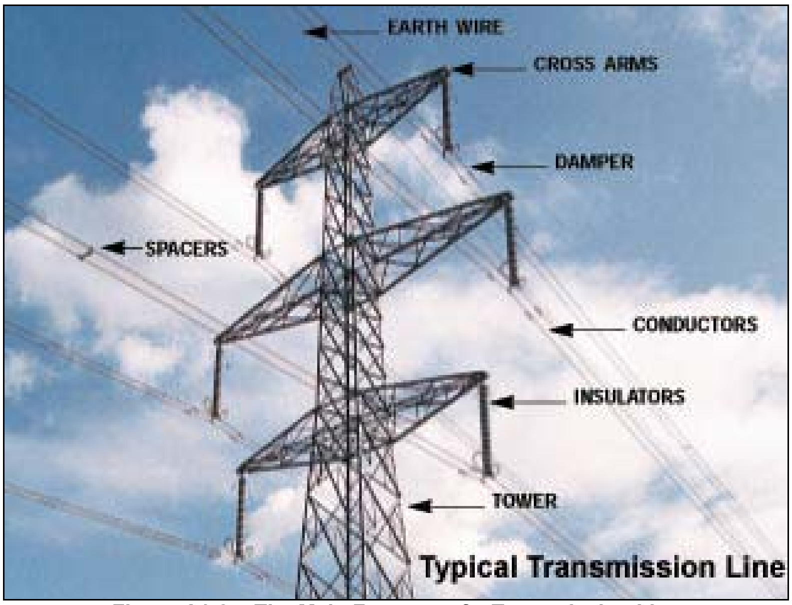


Figure A1-27: The Main Features of a Transmission Line

The maximum thermal ratings of the conductor systems fitted to the three most common suspension tower types are shown below

Tower Type	Conductor Type	Maximum Rating (at 75°C)
L2	2x 620 (GAP type, Aluminium Conductor Steel Reinforced)	3100 MVA
L6	3x700 AAAC (All Aluminium Alloy Conductor)	3820 MVA
L12	2x850 AAAC (All Aluminium Alloy Conductor)	2860 MVA

Some towers hold conductors that are not the largest conductor (in terms of power carrying capacity) that are possible for it to accommodate. In such cases, it is sometimes possible to achieve the necessary increase in rating by replacing the conductor system (reconductoring). This is always preferable to establishing a new overhead line route when considering reinforcement options as this method of reinforcement adds negligible, additional visual impact.

Safety clearances

Making contact or near contact with overhead lines is dangerous. As explained above, overhead electric conductors are normally bare (not insulated) and if an object approaches too closely it is possible that a flashover will occur with the likelihood of fatal or severe shock and burns to any person nearby. In order to prevent such incidents minimum safety clearance for overhead lines are prescribed. However, this important safety distance can add to the overall visual impact.

The clearance to an overhead line is calculated from the maximum temperature that the conductor could be operating at. As the electrical energy (or power) a conductor is carrying increases, this generates more heat due to the resistivity of the conducting material. As the temperature of the conductor increases it gets hotter, expands, and increases in length. This increase in length means that the conductor sags closer to the ground. The 'sag' of a conductor is the measurement of the lowest point that a conductor is expected to achieve at a given temperature.

Overhead transmission lines must conform to the specifications contained in the Electricity Safety, Quality and Continuity Regulations 2002. The minimum heights at which the conductors are strung between towers are given for lines operating at specified voltages.

Overhead lines are also constructed to conform to the Energy Networks Association's (ENA's) technical specifications which govern the minimum clearance to be maintained between the conductors and ground, roads, trees and objects on which a person may stand. Some examples of the application of safety clearances are illustrated in Figures A1-28 and A1-29. The minimum clearance to ground for a 400kV line is 7.6m and for a 275kV line is 7.0m.

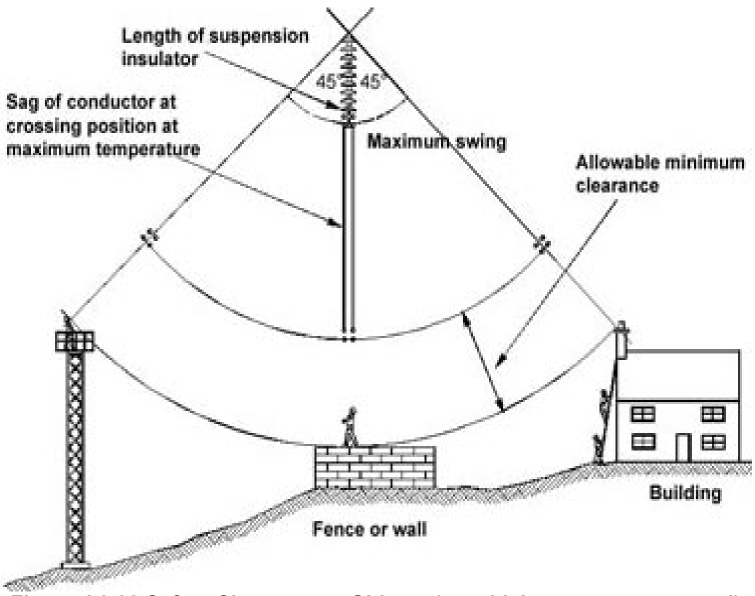


Figure A1-28 Safety Clearance to Objects (on which a person can stand)

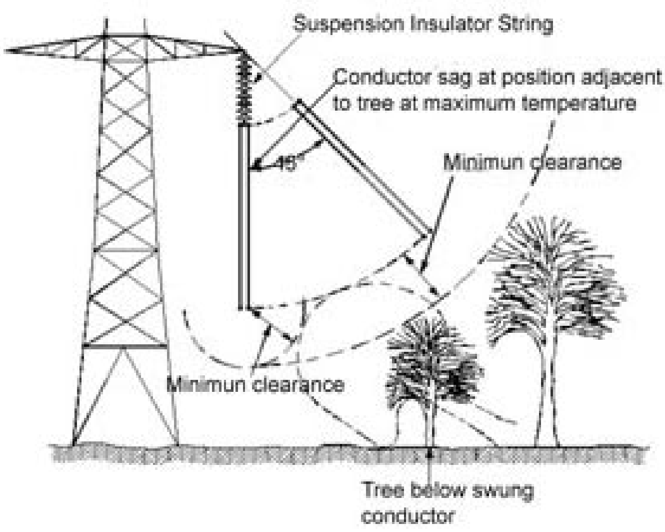


Figure A1-29 Safety Clearance to Trees

Appendix 2 – Planning Transmission Capacity

1.1 Characteristics of Transmission and the Electricity Market

The onshore electricity transmission system, as it exists today, has been built up over a period of time around the prevailing generation and demand background. It takes the electricity produced by generators across Great Britain and transmits it over large distances to points where the lower voltage, distribution networks take it further to the actual demand consumers who buy their electricity from suppliers. The transmission system is designed to ensure that electricity demand can be supplied at times of peak demand and to facilitate competition in the electricity market in an economic and efficient manner.

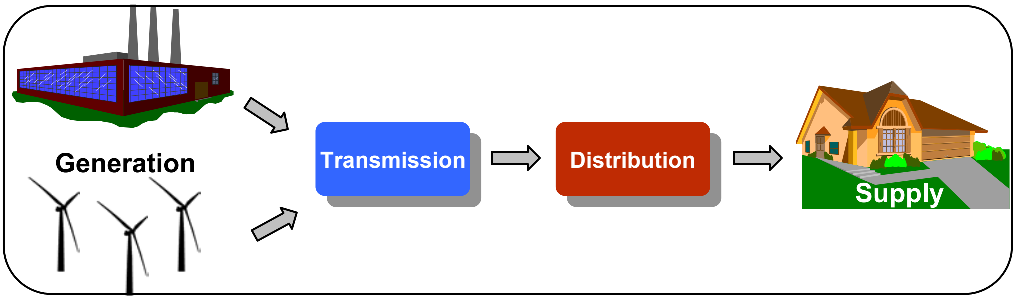


Figure A2-1: Electricity Industry Structure

There are several fundamental characteristics of electricity transmission in Great Britain that affects the design of both the transmission system and the electricity market that it exists to support:

- The physical assets and operation of the transmission and distribution systems are treated as natural monopolies due to the economies of scale and scope. It is clearly sensible, both for reasons of economics and reliability, that all components of the network are connected to the same system;
- Electricity cannot currently be stored economically on a large scale and the balancing of generation and demand must therefore occur instantaneously across the network;
- The flow of electricity across the network is dictated by the laws of physics, rather than any contractual arrangements that may be in place. These flows are heavily influenced by the characteristics of the network as well as the relative location of generating units to the demand and to each other;
- The actions of one user connected to the system can, almost instantaneously, impact on all other users of the network;
- Network reinforcements are 'lumpy' in nature, so that investment in the network cannot be made simply on a MW of capacity per MW of additional electricity flow basis.

A2.2 Planning Future Capacity on the Transmission System

In assessing the need for additional capacity on the transmission system, transmission owners (including National Grid Electricity Transmission in England and Wales) are required by their transmission licences to design according to the minimum, deterministic criteria outlined in the GB System Security and Quality of Supply Standards (GB SQSS) complemented with a limited amount of additional cost benefit analysis. The GB SQSS are intended to ensure that the transmission network is developed and operated to facilitate a competitive energy market, while also ensuring an adequate level of demand security. The criteria for designing the system to accommodate new generation falls into two parts: *Design of Generation Connections* (Section 2 of the GB SQSS) and Design of the *Main Interconnected Transmission System* (Section 4 of the GBSQSS). These standards are currently under review, as part of the Fundamental Review of the GB SQSS, under the direction of the GB SQSS Review Group[A].

Generation Connections

The generation connection standard (Section 2 of the GB SQSS) applies to the transmission circuits in the immediate vicinity of a new generation connection point or group of connection points. In essence, it requires sufficient transmission capacity to carry the full output (registered capacity) of all generators in the group for certain defined outages of transmission plant. Typically, the most severe outages considered are the loss of a double circuit transmission line or the outage of one transmission circuit followed by the loss of another.

Demand Security

Underlying the GB SQSS is the concept of *Demand Security*. Future electricity demand is uncertain, both in magnitude and geographic distribution, due to weather variations and simple forecasting error. Generating units inevitably suffer breakdowns in service, and new generators may also suffer delays in commissioning. There is thus always a finite risk that the national electrical demand might not be met in any given year, particularly if the weather is adverse. This risk is managed by aiming to have the installed generation capacity exceed the central forecast of maximum demand by a margin – the *planning margin* – which is currently set at 20%.

The design criteria for the Main Interconnected Transmission System (MITS) are applied to the transmission network as a whole and extend this philosophy. It aims to provide enough transmission capacity to allow any available generation to meet any distribution of demand, within reasonable limits of uncertainty.

[A] http://www.nationalgrid.com/NR/rdonlyres/67B20E95-61EF-4532-8557-659F7CD6D12A/15792/120207GBSQSSReviewGroupToR_FINAL_.pdf

Generation Availability and Output Variations

Currently, the generation fleet in Great Britain is largely composed of conventional coal, gas and nuclear units with a peak-demand availability of greater than 80%, thus limiting the possible range of input assumptions to the analysis. Unless restricted by breakdowns, conventional generators normally run at, or close to, their maximum output since this is their most efficient mode of operation. Renewable generation exploits intermittent, variable and uncontrollable energy sources such as wind or solar energy. Wind turbines will seldom operate at full output individually, and even more rarely collectively. An economic and efficient transmission system that incorporates substantial renewable generation will have to be designed to handle the variability of wind power together with its interactions with conventional plant availability and demand uncertainties.

Over the course of a year, the average output of wind generators can be expected to be of the order of 30% – 40% of their rated output, but wide variations will occur during the year. The network must be designed so that power can be exported from areas with wind generation when wind output is high, whilst allowing sufficient power to be imported to areas with wind generators when their output is low.

Main Interconnected Transmission System – Design Methodology

The design of the Main Interconnected Transmission System – "MITS" takes account of the demand and generation uncertainties discussed above. This is done by setting up a "Planned Transfer condition" based on a central forecast of demand and with generator outputs scaled by an average availability factor. Thus, if there is a generation capacity margin of 20% over and above the central demand forecast, the generator outputs are scaled by 83.3%.

Uncertainties in demand distribution and the generators that would actually run "on the day" are covered by calculating an "Interconnection Allowance" for each different part of the network. The interconnection allowances represent the departures from the planned transfer that could typically occur under real operating conditions. The transmission network is designed to be secure against contingencies (e.g. the loss of a double-circuit transmission line) for combinations of the planned transfers and the interconnection allowances.

The criteria in the current GB SQSS for design of the MITS are applicable to a system with conventional generation and so need to be developed to encompass renewable generation also. This has been the subject of much recent work in the UK which continues under the auspices of the Fundamental Review of the GB SQSS referred to above. Modified standards arising from that Review will not come into force before 2010, so the analysis for this report has been done using the same interim method used for the 2008 Seven Year Statement, and outlined in Chapter 7 of that document.

The interim method adapts the "planned transfer" approach, based on the following observations about wind generation:

- The average load factor for wind generators in the winter period is about 40%
- Wind generators rarely operate at their rated output; a group of turbines will deliver approximately 90% of their annual energy at output levels below 60% of their rating.
- Over a wide area, there is a low probability that all wind generators will produce maximum output simultaneously.

In calculating which generators to include in a design study to meet forecast peak demand plus a margin of 20%, wind generators are incorporated at 40% of their nominal output. Conventional generators are then added at 100% of nominal output, up to a total of 120% of peak demand.

This pattern of generation is then set up in power flow studies by entering wind generators at 72% of nominal output and conventional generators at 100%. When the total generation is then scaled uniformly to match the peak demand, the wind output will be between 50% and 60%, representing the variability of wind power, and the conventional generation will be at 70 – 83 % representing the plant availability and part-loading to cover wind variability.

Any part of the system must be secure against the MITS design criteria, and, if applicable, the generation connection criteria also (e.g. the generation connection standard may require local reinforcements in an area in addition to those needed for the MITS).

Reinforcement requirements may change, depending on the outcome of the review of the GB SQSS. The conclusions on reinforcement requirements in this document must therefore be taken as indicative, and not necessarily the final definitive requirement.

A2.3 Recovering the Cost of the Transmission System – Use of System Charging

Costs incurred by the Transmission Owners and the Transmission Operator in Great Britain are recovered through Transmission Network Use of System (TNUoS) charges and Balancing Services Use of System (BSUoS) charges respectively. In the case of TNUoS, the costs recovered also include an allowed revenue element agreed with OfGEM and reviewed on a five yearly basis.

The total revenue recovered under TNUoS consists of a geographically based element and a residual cost element. These costs are split between generation, paying 27% of the total and demand, paying 73% of the total.

The Transmission Licence places various legal obligations upon the holder. One of which (C5) is for National Grid to produce TNUoS charges which better achieve the "Relevant Objectives" of:

- Facilitating competition in generation;
- Reflection of costs incurred; and
- Taking account of developments in the transmission business.

In addition there are a number of charging objectives specified within the Charging Methodology, including the provision of:

- Transparency
- Simplicity
- Predictability
- Stability
- Reproducibility

The Connection and Use of System Code (CUSC), which all transmission connected users are required to sign up to lays out the requirement to pay TNUoS charges in accordance to the Statement of Use of System Charges.

The charging methodology for offshore transmission networks is yet to be determined. However, current proposals indicate that the generation connected to these networks will be paying for the majority of the costs through an offshore TNUoS element.

For onshore transmission a proposal is also under consideration for a flat use of system rate independent of location. This would have a particularly significant impact on those generators connected in Scotland.

Appendix 3 – Building Transmission Capacity

A3.1 Planning and Consents

Before major new electricity transmission infrastructure can be built onshore, National Grid normally has to seek and obtain a number of primary consents/permissions from government and/or the relevant local planning authorities. The nature and type of primary consent/permission differs between substations and overhead lines.

Substation developments require planning permission under the Town and Country Planning Act 1990 (as amended) from the appropriate Local Planning Authority (LPA) unless the works fall within the scope of permitted development as set out in Schedule 2, Part 17, Class G of the Town and Country Planning (General Permitted Development) Order 1995 (as amended). For some of National Grid's sites there is the possibility that certain substation works could be deemed to be permitted development and thereby exempt from the need for planning permission, providing they are to be wholly located on 'Operational Land'.

New high voltage overhead lines across land outside of National Grid's ownership presently require the prior consent of the Secretary of State for Energy and Climate Change under Section 37 of the Electricity Act 1989 (as amended). In the future, overhead line developments will be deemed to be within the category of nationally significant developments that are proposed to be included from 2010 within the scope of the new 'development consent' regime under the Infrastructure Planning Commission (IPC). The IPC is proposed to be established under the Planning Bill which is proceeding through its stages in parliament. Should any given future network reinforcement projects involve overhead line works requiring consent and new substation developments, then both would be consented by the IPC under the single consents process envisaged under the proposed new Planning Bill regime.[B]

Applications for Section 37 consent for new 275kV or 400kV overhead lines that would be greater than 15km in length must also be accompanied by a formal environmental impact assessment (EIA) under the Electricity Works (Environmental Impact Assessment) (England and Wales) Regulations 2000.

<u>Environmental Impact Assessment</u>

Overhead lines with a voltage of 220kV or more and a length of more than 15km which require consent under section 37 of the Electricity Act 1989 are included in Schedule 1 of The Electricity Works (Environmental Impact Assessment) (England and Wales) Regulations 2000 (as amended). These regulations implement European Directive 85/337/EEC as amended by Directive 91/11/EC which set out procedures for the assessment of the effects of certain projects on the environment. For all developments listed in Schedule 1 of the regulations, the preparation of an environmental statement is mandatory. As such, National Grid will always undertake an environmental impact assessment of all new high voltage overhead line routes of more than 15km in length and submit an environmental statement. For new overhead lines greater than around 2km, National Grid usually provides a formal Environmental Statement in support of the Section 37 consent application on a voluntary basis.

A separate list of developments is covered in Schedule 2 of the regulations. A Schedule 2 development project need only be subject to environmental assessment if it is likely to have a significant effect on the environment because of its size, nature or location. The regulations state that where proposals include a high voltage overhead line or an overhead line installed in a

[B] The Planning Bill has subsequently received Royal Assent on the 26th November 2008 sensitive area, the need for an environmental impact assessment will be determined on a case-by-case basis. National Grid will therefore carry out environmental impact assessments for some overhead line developments which fall into Schedule 2, dependent on consultation with the relevant local planning authorities and the outcome of the screening process.

Environmental statements are not required under the legislation for new substation proposals, however National Grid has given a commitment in its' Schedule 9 statement (see section A3.2) to undertake relevant environmental investigations and report on these in any application for consent for new works.

For both the present government consent and future Planning Bill processes, the relevant local planning authorities are important consultees along with other statutory bodies, non-statutory consultees and the public. Existing arrangements whereby the views of those bodies are sought and taken into account by both the developer and the decision-making body are proposed to be strengthened under the Planning Bill reforms, with the introduction of defined mandatory pre-application consultation provisions. National Grid will need to agree a pre-application consultation strategy for any given project with the relevant LPAs. That strategy will need to be advertised and consultations carried out that will also deliberate on alternative network reinforcement options that are under consideration. Any comments received as part of the consultation process are taken into account before a decision is taken on which option to take forward for detailed environmental impact assessment and an application for development consent.

In addition to (ideally) gaining the support, or at least acceptance, of the relevant LPA's, other consultees and the public affected by any new overhead transmission line, before it can be consented by the Secretary of State, the agreement of each landowner and tenant across whose landholding it will pass is also needed. If a relevant LPA objection cannot be overcome then presently the Secretary of State must hold a public inquiry into the Section 37 consent application. Similarly, if landowner/occupier agreements cannot be secured by voluntary means, then National Grid would have to apply to the Secretary of State for a necessary wayleave and a hearing would be scheduled by the Department to hear the particular concerns of the landowner before the Secretary of State takes a view on the necessary wayleave application.

A3.2 National Grid Amenity Responsibilities

The following sets out National Grid's amenity responsibilities as per the Electricity Act 1989, Schedule 9. Although the information described below is specific to National Grid as the onshore transmission owner in England & Wales, Scottish onshore transmission owners will also be bound by the same sections of the Act and will also have similar Schedule 9 statements.

Under section 38 of the Electricity Act 1989, National Grid has a duty in formulating proposals for new development to "have regard to the desirability of preserving natural beauty, of conserving flora, fauna and geological or physiographical features of special interest and of protecting sites, buildings and objects of architectural, historic or archaeological interest; and shall do what [they] reasonably can to mitigate any effect which the proposals would have on the natural beauty of the countryside or on any such flora, fauna, features, sites, buildings or objects."

National Grid is also required under Schedule 9 of the Act to produce and publish a statement setting out how it proposes to meet this obligation. The company's Schedule 9 Statement is available as a separate document.

http://www.nationalgrid.com/uk/LandandDevelopment/SC/Responsibilities/

As with other statutory undertakers, the Company is also obliged under the Environment Act 1995 and the Countryside and Rights of Way Act 2000 to be mindful of the purposes of National Parks and Areas of Outstanding Natural Beauty when considering proposals that have the potential to impact upon those nationally important landscape designations.

To guide the siting and routing of new high voltage electricity transmission infrastructure, National Grid also has sets of 'Rules' relating to the overhead line and substation developments – the Horlock and Holford Rules. Coupled with best practice approaches in environmental impact assessment, these provide a well accepted set of high-level governing principles underpinning the approach to be taken in seeking to minimise the potential environmental impacts associated with such new installations. Attachment 3 provides an indicative construction programme highlighting the development stages associated with a new overhead line and substation project.

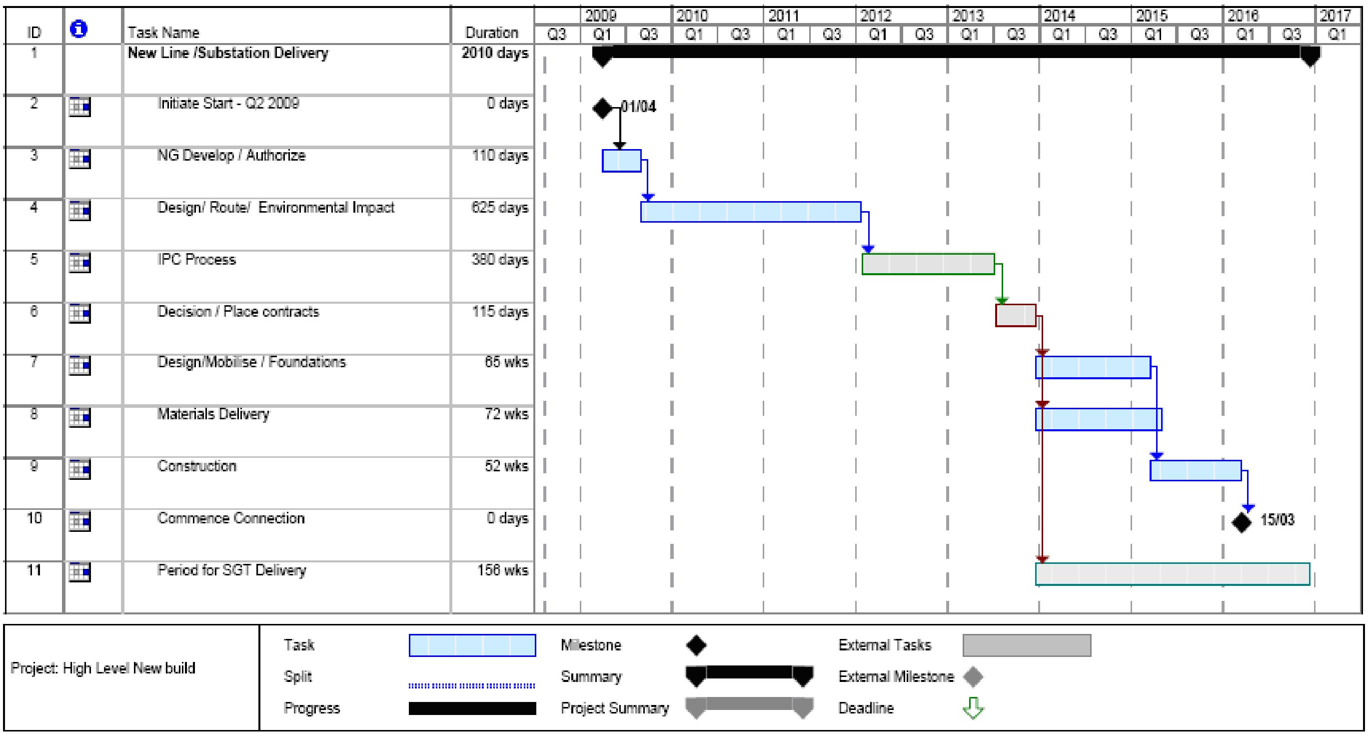


Figure A3-1 – Overview of Programme for New Overhead Line and Substation Deliver with IPC

A3.3 Impact of System Outages

Any planned work undertaken on the onshore transmission system requires the affected equipment to be taken out of service for a period of time. In some circumstances, it may be necessary for adjacent equipment to also be taken out of service if significant health and safety risks are apparent to site personnel.

The numbers of outages that can be taken on the transmission system over the course of a year are limited due to the finite capacity on the system and the need to continue supplying demand as well as facilitate an efficient energy market. It is for this reason that access to the system is planned years in advance and constantly reviewed to facilitate maintenance, asset replacement and system reinforcement. Access is usually limited to between April and October each year, corresponding to the times when system demand is at its lowest. This is illustrated in Figure A3-2, below, which shows typical winter and summer demand profiles. It is only at these times, when demand is normally less than two thirds of its peak, that work can take place.

Given the volume of potential system reinforcement identified through this analysis and the challenging timescales in which it must take place, access to the transmission system will need to be coordinated very carefully if it is not to become a constraint in getting the necessary work done.

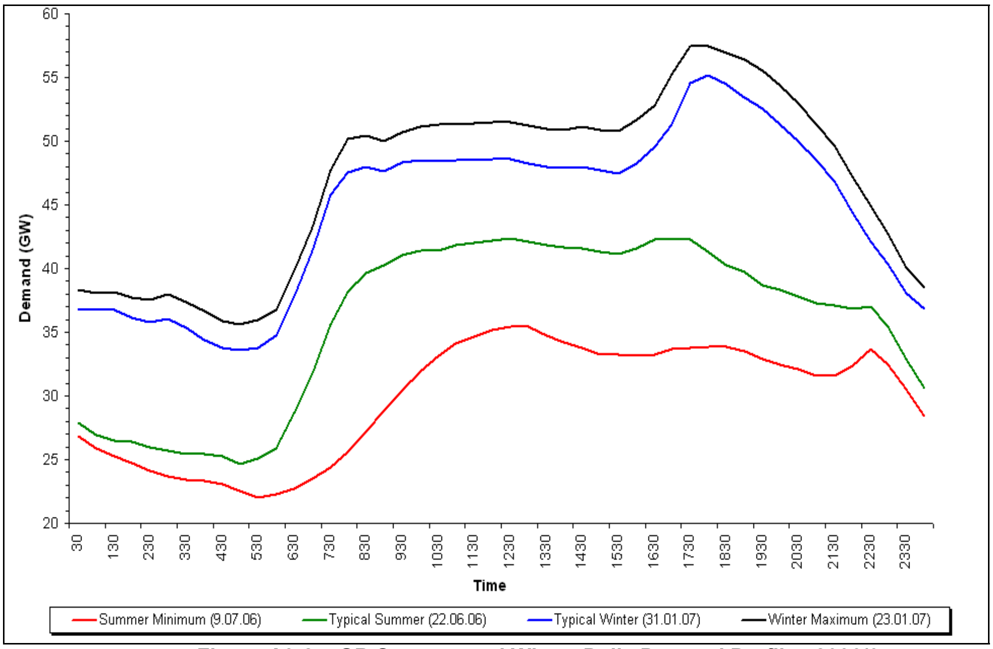


Figure A3-2 – GB Summer and Winter Daily Demand Profiles 2006/07

The nature of the planned system outages, discussed above, can be categorised as follows:

- *Maintenance Outages*
  Equipment outages required for routine maintenance purposes.

- *System Construction Outages*
  Equipment outages for the construction or modification of the system that is not exclusively for the benefit of a specific user directly connected to the transmission system. This includes system reinforcements where more than one user benefits from any additional capacity provided.

- *Users Connection Outages*
  Equipment outages for the construction or modification of the system that facilitates the connection of a specific user directly connected to the Transmission System.

- *Third Party Outages*
  User equipment outages, for example on a distribution network operator (DNO) system.

There is a high level of interaction and coordination between these outages across the country being programmed into a consolidated plan each year. There is a detailed process for securing access that is aimed at maximising the efficiency of the system, which requires that system access needs are identified and sought several years ahead of the actual outage dates.

In practice, it is unlikely that even work associated with the uprating of a long double circuit overhead line route would be completed within a single outage season (i.e. between April and October in one year). Where new routes are proposed, obtaining planning consents will impact on when construction can take place and in which specific year the outage will be requested. Particularly controversial routes may be consented after an indeterminate length of time.

A related concern is the amount of engineering resource significant changes to the transmission system would require. At present there is a shortage in the amount of engineering resource to design, construct and commission the existing planned transmission system modifications each year. The accompanying difficulty for the work highlighted through this analysis is the potential for rescheduling and postponement of work, should insufficient resource be available to meet timescales.

Any site work would also have to be linked to the lead times of manufactured equipment and when it is envisaged installation work can commence. The lead time for procuring key products and availability of manufacturing capacity could be a substantial limitation if, as anticipated, there is a global increase in demand for infrastructure.

There are a number of external factors that will influence when transmission system outages can be taken. If manufacturing supply chain and resource issues can be overcome, there is still a requirement for a coordinated approach in planning outages, as described above.

A3.4 Costing Methodology

Costs for the various components of the overall design have been based on:

- *Onshore substation work*
  This has been budgeted from either site specific estimates for revisions to existing installations, using National Grid's cost estimating database, or using 'generic' estimates around a range of basic 'building blocks' – e.g. for new substations a series of standard arrangements have been assumed and cost estimates created for these. As such, costs may vary when local requirements at individual locations are taken into account.

  At each of the National Grid substations an evaluation of land requirements and availability was undertaken to determine if additional land and planning consents would be necessary. Where appropriate, estimates for undertaking this work have been included.

- *New overhead lines*
  Where these are proposed, a generic cost estimate has been used, based on 'standard' circumstances (i.e. foundations, access, and routing assuming reasonable sections of overhead line are in straight lines and do not require significant quantities of angle towers for changes of direction).

Onshore Transmission System Design Cost Inclusions	Cost Exclusions
• Busbar extensions for new connection bays • Busbar protection, for new connection bays • Substation extensions, including fencing, surfacing, drainage and internal access roads • Land purchase • Surveys and environmental impact assessments • An allowance for site screening • Obtaining planning permission, or overhead line consent for the National Grid works. • Substation reconfiguration costs • Additional circuit bays for infrastructure modifications • Overhead line diversions into new substations • Where combined with a DNO connection all costs associated with providing this, SGT's and LV connections. • All civil works for National Grid assets • Protection and Control changes, including remote ends of modified circuits. • Overhead line construction or re-stringing • For new sites/routes an allowance for siting and routeing studies and consultation. • Works award process costs.	• System outage constraints • Circuit outage – system uplift costs • Consent /planning permission mitigation • Third Party Costs • Reactive compensation

Basis of Onshore Transmission Costs

NB: All costs are based on 2008 price levels

Where new overhead line (OHL) routes are proposed, route lengths have been estimated assuming that routes will avoid environmentally and visually important areas. In estimating the cost of these circuits no allowance has been made for the potential need to install sections as underground cable, apart from some line entries to substations where it is apparent that this will be required. The overall cost of any new OHL routes could increase if sections of underground cable are required.

The major new 400kV infrastructure overhead line routes considered have all been estimated on a 'stand-alone' cost. The possibility remains, that for certain sections mitigation measures may be identified where adopting and rebuilding an existing distribution network operator (DNO) 132kV route may be appropriate. No allowance has been made for this or for the creation of any additional DNO supply points that may arise as a consequence. Several local options have considered replacing DNO 132kV circuits with 400kV lines plus new DNO connections; these are identified in the wind farm specific descriptions.