DOGGER BANK
TEESSIDE

May 2012

Appendix A
Project Description

Preliminary Environmental Information 1 (PEI1)

Dogger Bank Teesside PEI1
Appendix A – Project Description

Document no. :	Contract no. (if applicable):	Project:
		Dogger Bank Teesside

Overview:

Information on the initial design parameters, likely construction methodologies and any relevant operating characteristics associated with the delivery of Dogger Bank Teesside. Produced to support consultation under section 42 and section 47 of the Planning Act 2008 as amended.

Prepared by:	Date:	Signature:
Forewind	May 2012	
Approved by:	**Date:**	**Signature:**
Forewind	May 2012	

Contents

Table of tables

Table of figures

1 Introduction

Purpose of this document

1.1 This document has been produced to support consultation under sections 42 and 47 of The Planning Act 2008 (the Planning Act) (that is to say pre-application consultation) which is currently being undertaken by Forewind in relation to its offshore wind farm development proposals for Dogger Bank Teesside.

1.2 It includes information on the initial design parameters, likely construction methodologies and any relevant operating characteristics associated with the delivery of Dogger Bank Teesside so that stakeholders can better understand the likely effects of the development proposals.

1.3 Further information about the approach to environmental survey and assessment and the site selection process can be found in the Dogger Bank Teesside Preliminary Environmental Information 1 (PEI1) Non-Technical Summary (and in more detail in *Appendix B: Dogger Bank Teesside Environmental Impact Assessment Scoping Report* (*The Scoping Report)* and *Appendix C: The Site Selection Report*) which has also been produced to support this consultation.

1.4 Forewind is seeking comments on the Project Description as part of the consultation. **The deadline for consultation responses is Friday 22 June 2012. If you would like to respond to this consultation, it is important that your comments are received by Forewind before the deadline.**

1.5 Please send responses to Forewind using the details below -

Website:	www.forewind.co.uk
e.mail:	info@forewind.co.uk
Phone:	0800 975 5636
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1.6 Full details of the consultation and how to respond can be found in the Dogger Bank Teesside PEI1 Non-Technical Summary.

Background

1.7 Dogger Bank Teesside, the subject of this consultation, is the second stage of Forewind's development of the Dogger Bank Zone. It will comprise up to four offshore wind farms, each with a generating capacity of up to 1.2GW, which will connect into the national grid just south of the Tees Estuary. The Dogger Bank Teesside projects will have a total combined generating capacity of up to 4.8GW.

1.8 Forewind currently expects that at least two of these wind farms will connect to the existing Lackenby Substation, which is near Eston. Up to two further wind farms are likely to connect to a new substation, which National Grid plans to build as an upgrade to an existing facility in Teesside. The location of the new substation is yet to be finalised, but is also likely to be in the industrial area of Teesside, south of the Tees Estuary.

1.9 The offshore infrastructure for the Dogger Bank Teesside projects will comprise up to four wind farms, each of up to 1.2GW installed capacity, offshore collector and converter stations, offshore accommodation platforms, subsea inter-array cables and offshore export cable systems to a landfall(s) on the Teesside coastline.

1.10 The onshore element will include up to four underground cable systems from the landfall locations to the onshore converter stations, up to four converter stations and up to four buried cable systems to the National Grid substation(s).

1.11 The joint development of these four projects at Teesside during the pre-application phase is intended to be helpful to stakeholders, by ensuring that at each stage of the development process they have access to information on the full extent of Forewind's development proposals at that location. By undertaking a joint consultation process for all four projects, Forewind hopes to make better use of stakeholders' time and reduce stakeholder fatigue by allowing stakeholders to make representations on either one or all of the Dogger Bank Teesside projects at the same time, as they feel appropriate. It is proposed that this will help to ensure the most transparent approach to development throughout the pre-application phase.

1.12 At the end of the development process Forewind will submit between one and four development consent order (DCO) applications to the National Infrastructure Directorate (NID) of the Planning Inspectorate. The consent application strategy will be determined following consultation with stakeholders, through information gathered during the Environmental Impact Assessment (EIA) process, following discussions with the NID and after further consideration of how these projects might subsequently be delivered.

2 Project Description

Project Components

2.1 Offshore wind farms generate electricity from the energy that is available in the wind. They comprise wind turbine generators (WTGs) and the associated electricity infrastructure that is required to ensure that the electricity which is generated can be connected into the national grid.

2.2 The key components of an offshore wind farm are –

- WTGs - Wind energy causes the blades on a WTG to rotate which rotates a generator in order to transform the kinetic energy of the wind into electricity;
- Subsea inter-array cables – carry the electricity generated by offshore WTGs to offshore collector stations and then on to offshore converter stations;
- Offshore collector stations – transform electricity generated by WTGs to a higher voltage ready for transmission to the offshore converter station – this helps to minimise losses;
- Offshore converter stations – change the high voltage alternating current (HVAC) electricity from the offshore collector stations to high voltage direct current (HVDC) in order to further minimise losses within the export cables;
- Export cable systems – transmit the HVDC electricity from the offshore converter stations to the onshore converter stations;
- Onshore converter stations – convert the HVDC electricity into HVAC electricity so that it can be connected to the national grid;
- HVAC cable systems – connect the electricity from the onshore converter stations into the national grid substations; and
- National Grid substations – owned and operated by National Grid, these substations provide a connection into the UK's electricity network.

2.3 A fuller list of components and further information about them and the associated construction methodologies is included below.

2.4 Figure 1 is a schematic diagram which shows how these key components are connected together in a typical offshore wind farm.

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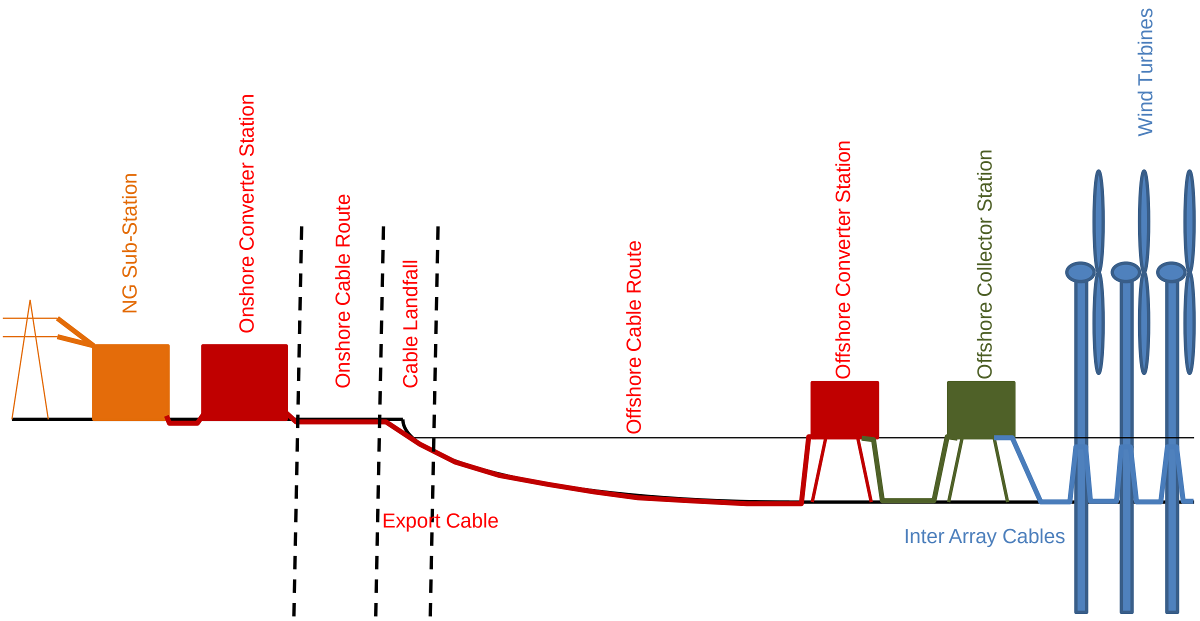

Figure 1 Schematic diagram of an offshore wind farm project

2.5 Dogger Bank Teesside comprises up to four offshore wind farms each with a generating capacity of up to 1.2GW, and associated onshore and offshore infrastructure. The proposals will include consideration of any temporary or permanent works required for the construction, operation and decommissioning of the project infrastructure.

2.6 Forewind's proposals include the above infrastructure up to the point of connection into National Grid's transmission network. The works on the transmission network that may be required to connect Forewind's projects (the "Enabling Actions") will be consented, constructed and operated by National Grid.

2.7 National Grid has not yet completed the engineering studies necessary to define the Enabling Actions at Lackenby Substation, but it is likely that they will only involve modifications to the existing infrastructure. More extensive works are expected to be required to facilitate the connection of the latter two Dogger Bank Teesside projects, potentially requiring the construction of a new 400kV substation in the industrial area of Teesside, south of the Tees Estuary. National Grid is at an early stage in determining the required Enabling Works, and more clarity will be provided once available.

2.8 The table below indicates the maximum number of components shown in the schematic that are likely to be included in Dogger Bank Teesside. Further information on these components and their installation methodologies are included in the remaining sections of this report.

Table 1 Maximum number of key project components[1]

Key Project Component	One 1.2GW project	Four 1.2GW projects
Wind turbine generators[2] (assuming a 3MW machine)	400	1600
Offshore collector station platforms	Up to 4	Up to 16
Offshore converter station platforms	1	4
Number of HVDC cable systems connecting offshore converter stations to the onshore converter stations	1	4
Number of buried joint transition bays at the landfall	2	8
Onshore converter stations	1	4
Number of HVAC cable systems connecting onshore converter stations to National Grid's substations	1	4

2.9 The construction programme for Dogger Bank Teesside will be dependent on a number of factors which include –

- The grid connection dates in the connection agreements with National Grid (which may be subject to change);
- The date that development consent is awarded; and
- The availability and lead times associated with the project components.

2.10 These factors will determine whether the 1.2GW projects will be constructed concurrently or sequentially. The EIA will need to assess the effects associated with a range of construction scenarios in order to provide the organisation who

[1] Note that this table describes the maximum number of key components shown in the schematic drawing Figure 1 It is not intended to provide a full list of components – further information on these is given in the sections that follow

[2] Note that Forewind's proposals include a range of turbine options of between 3MW and 10MW machines. Hence the number of turbines required to achieve the total generation capacity of 1.2GW is between 400 (for a 3 MW turbine) but could be as low as 120 (for a 10MW turbine).

will build the projects with the flexibility to construct them in accordance with these external influences.

2.11 Forewind's current grid connection date for the first Teesside project is in 2017 which means that the earliest works could start onshore is in 2015.

Rochdale Envelope

2.12 Due to the uncertainties associated with the construction timescales for the projects, the supply chain and the technologies that might be available, Forewind will establish a Rochdale Envelope[3] against which it will undertake its EIA.

2.13 The Rochdale Envelope incorporates the worst-realistic case design parameters (e.g. maximum number of turbines) that might potentially be part of the final project design. Undertaking an EIA against these parameters is intended to provide the ability to seek consent for any project design that falls within those parameters and therefore allows a fixed degree of flexibility to finalise the design parameters post consent.

2.14 The Rochdale Envelope will be determined following further engineering design, environmental impact assessments, consultations with the relevant statutory organisations and agreement on Forewind's consent strategy. Forewind will present its Rochdale Envelope and provide further detail on the range of design parameters that it is intended to incorporate, in the Environmental Statement produced to support its application(s). Forewind will consult stakeholders on the draft Environmental Statement in advance of submitting the application.

[3] Case law (i.e. *R.V. Rochdale MBC Ex Part C Tew* 1999 – "the Rochdale case") set a precedent that "indicative" sketches and layouts, etc, cannot provide a sufficient basis for the determination of applications for outline planning permission for EIA development. In respect of DCO consent, the final scheme constructed must have been covered by the scope of the EIA.

3 The Offshore Project Components

Overview of the Offshore Project Components

3.1 A fuller list of the offshore project components proposed for Dogger Bank Teesside is provided below -

- Offshore wind farm arrays allowing for the production of up to 4.8GW (or up to four projects of up to 1.2GW each) consisting of wind turbine generators (WTG), foundations and scour protection measures;
- Offshore collector and converter substation platforms, foundations and scour protection measures;
- Offshore operations and maintenance infrastructure, such as accommodation platforms, permanent moorings, and navigational buoys and scour protection measures;
- Subsea inter-array cables:
  - Between the WTGs; and
  - Between WTGs and offshore collector substations
- Inter-platform cable connections:
  - between collector substation platforms;
  - between collector substation platforms and HVDC converter substation platforms; and
  - between HVDC converter substation platforms
- Offshore export cable systems, carrying power from the offshore HVDC converter substation platforms to the landfall(s), or possibly to other wind farm projects within the zone;
- Crossing structures at the points where project cables cross other project cables, existing subsea cables or pipelines;
- Structures for protection of any offshore cables where sufficient burial is not achievable; and
- Offshore meteorological masts and other metocean monitoring equipment.

3.2 Further information to describe these components and the associated installation methods is included in the sections below.

Wind turbine generators (WTGs)

3.3 Offshore wind turbine technology is evolving rapidly and it is anticipated that WTGs of up to 10MW may be available within the timescales of this project. This results in a range of possible dimensions: future 3MW WTGs would be expected to have rotor diameters of up to around 118m, and tip heights of up to 165m; and WTGs in the region of 10MW might potentially have rotor diameters of up to 216m and tip heights up to 263m. Based on these estimates this means that a wind farm project of 1.2GW may range from 400 x 3MW WTGs to 120 x 10MW WTGs, or variations in between.

Figure 2 An offshore wind turbine generator

Wind turbine foundations

3.4 A wide range of foundation options are potentially available, contingent on the outcome of ground investigations, detailed design studies and environmental assessment. This range changes continually as new sub-types are developed, but can be considered as grouped within the following categories:

Monopile

3.5 Usually constructed from welded steel tubular sections (tapered or cylindrical) driven vertically into the seabed using piling hammers, and sometimes drilling rigs. Research and development is currently considering the use of large steel monopiles of around 8m in diameter. An alternative monopile solution (currently under development) uses a steel reinforced concrete design with indicative diameter of 9m to 11m for larger WTGs.

Figure 3 An installed monopile foundation and transition piece

Multi-pile (or jacket):

3.6 A family of foundation options, typically consisting of three or four main legs which are linked by a supporting matrix of cross-braces. Indicative dimensions for large multipile foundations include main tubular diameters of up to 2.5m, and a width of base at seabed of around 30 to 40m. Each leg is usually secured by a pin pile, driven into the seabed and fixed into a sleeve, but this can also be achieved using other techniques, such as suction caissons as described below.

Figure 4 Jacket foundations for 5MW turbines on the Alpha Ventus project

Tripod

3.7 Similarly to the multipile foundation options, this includes a family of foundation types. All include multiple legs (usually three) supporting a single tubular support for the WTG, and they may be asymmetrical in some cases. Indicative dimensions for large tripods are a central tubular section diameter of around 8 to 12m, supporting braces of around 3m, and piles of around 3m diameter. The tripod is driven into the sea bed in a similar manner to the multi-pile concepts above.

Figure 5 A tripod foundation for a 5MW turbine prior to installation (reproduced from Alpha Ventus.de)

Gravity base structure (GBS)

3.8 A heavy steel, concrete, or steel and concrete combination base, sometimes including additional ballast substances, which sits on the seabed to support the

WTG tower. Gravity bases vary in shape and include conical, as well as cylindrical or hexagonal sections, with indicative base diameters up to 55m. In all cases, the gravity base structure is placed on a pre-prepared area of seabed. Seabed preparation consists of removal of soft, mobile sediments and the levelling of an area which may include the addition of gravel or rock dumping. Gravity base foundations may be designed with steel skirts around the perimeter of the base, which penetrate into the soil and also allow under-base grouting.

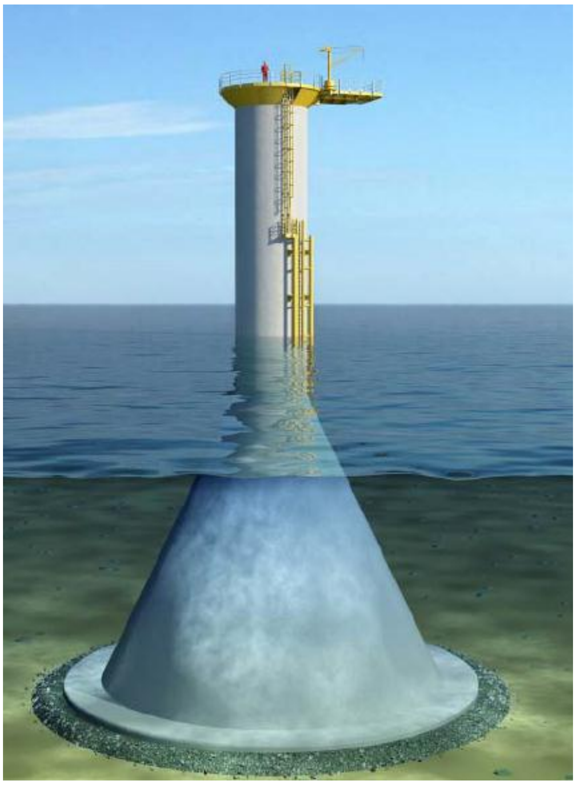

Figure 6 Conical gravity base foundations

Suction caisson (suction bucket)

3.9 Based on a structure comparable to an upturned bucket (and often known as a suction bucket foundation) that is lowered to penetrate into a pre-prepared (levelled) seabed. Other than seabed surface preparation, the installation process does not result in the generation of spoil, nor does it require piling, as installation is achieved via use of suction inside the "bucket". For smaller WTG classes, caissons may be used individually with an indicative diameter of around 30m, penetrating to around 15m into the seabed. For larger wind turbine classes, the use of suction caisson foundations may be as part of a multipile or tripod structure and thus should be considered in conjunction with the applicable dimensions above.

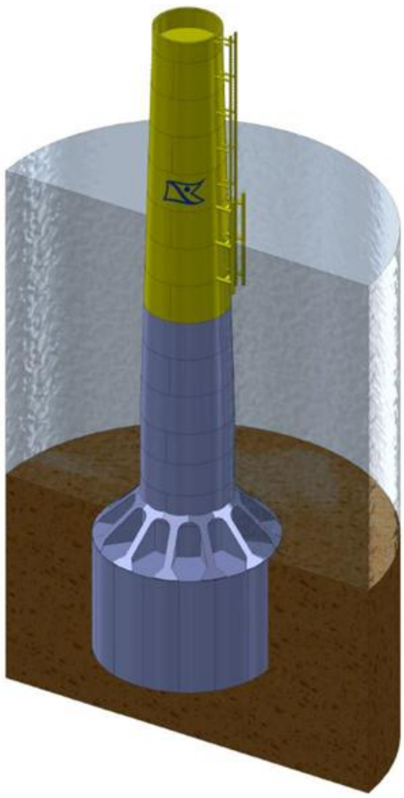

Figure 7 A suction caisson (suction bucket) foundation

Collector substation platforms

3.10 Collector substations will receive power from the inter-array cable systems and step up the voltage for export to a HVDC converter substation. The location and number of collector substations will depend on the array layout, number and capacity of wind turbines and the installed capacity of the wind farm. The export voltage will be determined by detailed studies, but is likely to be in the range of 132kV to 400kV.

3.11 The number of collector substations for the project will be determined based on detailed studies, but it is likely that, for a single project, there will be up to four collector substations for around 1.2GW of generation capacity. The largest single collector substation platform seen to date is around 600 MW, and the dimensions for such a platform could typically be 75 (l) x 75 (w) x 85 (h) meters including cranes, but the final capacity and dimensions for these offshore collector substation platforms will be determined through detailed design.

3.12 Therefore, for four projects of up to 1.2GW each, there could be up to 16 offshore collector substations in total for the Dogger Bank Teesside projects.

Figure 8 Inner Gabbard collector substation

Converter substation platforms

3.13 Given the distance offshore, the likely technical solution for the project's grid connection will be Voltage Source Converter High Voltage Direct Current (VSC HVDC) technology. This technology provides for significantly lower power losses over long distances than High Voltage Alternating Current (HVAC) technology. HVDC technology requires a converter substation at each end of the export cable, to convert the power between AC and DC.

3.14 The number of converter substations for the project will be determined based on detailed studies, but it is likely that, for a single project, there will be a single converter substation for around 1.2GW of generation capacity, and this may be either standalone or associated with collector substations. The dimensions for a 1.2 GW offshore converter substation platform could typically be 125 (l) x 100 (w) x 105 (h) metres including cranes, but the final capacity and dimensions for these offshore converter substation platforms will be determined through detailed design.

3.15 Therefore for four projects of up to 1.2GW each, there could be up to 4 offshore converter substations in total for Dogger Bank Teesside.

Substation platform foundation concepts

3.16 There is a range of available foundation types for both the collector and converter substations, such as a jacket, gravity base, suction caisson, multipile-type foundation, or self-installing jack up or semi-submersible solutions that will be floated in and placed on the seabed, but this will be confirmed following detailed design work.

Spoil

3.17 Spoil may be produced during the installation of the WTG, collector or converters station foundations, either through drilling or suction dredging. Where seabed preparation is anticipated (i.e. for gravity base and suction caissons) base locations may be levelled by suction dredging (or similar) to an estimated average depth of approximately 3m below current seabed levels. Spoil could be disposed of on site, or off-site at a licensed spoil disposal area. Any disposal on site will be subject to assessment and licensing, as appropriate.

Scour protection

3.18 Scour protection may be required around any offshore structures installed by the project. Should scour protection be required there are a number of options available, selection of which will depend on the final foundation or structural design, ground conditions, scour assessments and environmental assessment. Typical options include:

- Protective aprons;
- Mattresses;
- Flow energy dissipation (frond) devices; and
- Rock and gravel dumping.

Inter-array cabling

3.19 Inter-array cabling will transmit power from the individual WTGs to an offshore collector platform. Generation from the WTGs will be collected either through separate radials, ring systems, branched cable systems or a combination of these. The final design of the inter-array cable collector system will depend on the array layout, seabed conditions, number and capacity of the wind turbines and the total installed capacity of the wind farm.

3.20 Inter-array cables are typically single cables containing three cores (normally of copper) and a fibre-optic cable to transmit data for the wind farm control and protection systems. The three cores are bundled together and protected by armouring to reduce the risk of damage to the cable during installation or from external impacts. The cables could have a diameter of around 90-150mm for 33kV (industry standard), but may be larger for higher voltages (up to 72 kV).

3.21 The total length of inter-array cabling will depend on the actual layout and size of the wind farm, number of offshore collector substations and need for micro-routing around obstacles or constraints on the seabed.

Figure 9 Inter-array cable installation vessel: Northern River, Multi Role Installation and Trenching DPII

Offshore export cabling

3.22 Export cabling technology will vary for different components of the project as detailed below:

Collector to converter export cabling

3.23 Depending on the transmission voltage and the capacity of the collector substation, there are likely to be one to four AC export cables from each of the collector substations to the converter substation. The voltage will be determined by detailed studies, but is likely to be in the range of 132kV to 400kV. The export cables' conductors will be made of copper or aluminium. The maximum diameter of one cable may be around 300 mm.

Inter-project export cabling

3.24 There may be a need for connections linking the Dogger Bank Teesside projects with further developments within or between the tranches. The final offshore network design is to be determined during detailed optioneering and onshore grid compliance studies. If required, the cable technology and voltage level for these inter-project links are likely to be similar to those connecting collector and converter substations within a project.

Offshore HVDC export cable systems

3.25 The design of the HVDC connection to shore will determine the type of export cabling required. The base case design will consist of a pair of HVDC cables for each converter substation, one with a high positive voltage, and one with a high negative voltage relative to earth. A typical voltage for this design could be up to +/-550 kV depending on the power to be transmitted, the connection distance and detailed design.

3.26 The two HVDC cables in a circuit are preferably bundled together in the same trench until they approach the landfall location, where they are sometimes separated for Horizontal Directional Drilling (HDD) through to the onshore jointing bays. However it may be required to install the two cables separately in separate trenches, some distance apart.

3.27 Spacing between each offshore export cable system (cable pair) has yet to be determined, and will be driven by a number of considerations, including environmental considerations, seabed conditions, interactions with other marine users such as fishing and shipping activities, and ensuring adequate protection of the offshore cables. It will be important to ensure that the cable systems are installed sufficiently far apart to minimise the chance of damage to multiple cable systems from a single incident.

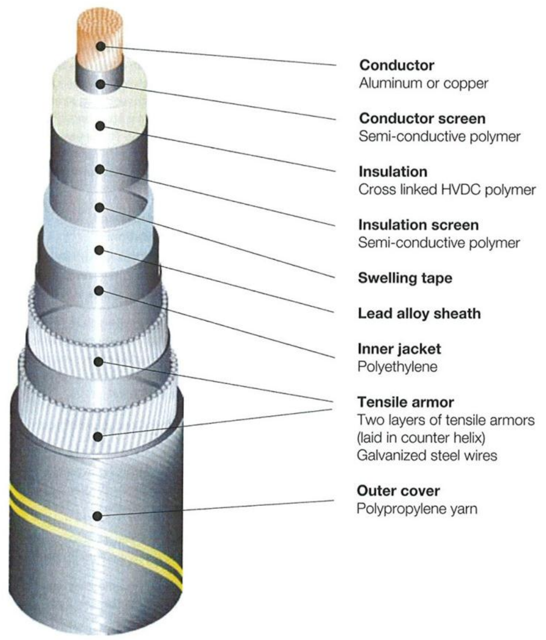

Figure 10 Offshore export cables – a cutaway view of a typical deep sea cable [Courtesy ABB]

Meteorological masts and metocean equipment

3.28 A number of meteorological monitoring stations (masts) will be installed within the Dogger Bank offshore wind farm zone and one or more of these may be proposed for Dogger Bank Teesside. These consist primarily of a tall tower fitted with anemometers for measuring wind data, mounted on a foundation similar to that of a smaller WTG. This mast may also include a wide variety of other instrumentation both mounted on the mast and deployed around it. Meteorological masts are essential to provide meteorological and oceanographic (metocean) data.

3.29 The metocean data are used for designing and optimising the wind farm design prior to installation and subsequently for monitoring wind farm performance. The final locations and foundation option for the proposed meteorological masts will be determined during the detailed project design process.

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Figure 11 An offshore meteorological mast

3.30 It is possible that some metocean monitoring equipment will also be installed separately to the main meteorological masts. This could include technologies such as waverider buoys (floating buoys designed to measure wave data) and acoustic waves and currents (AWAC) units, which are seabed mounted equipment designed to measure wave, current, and water level data.

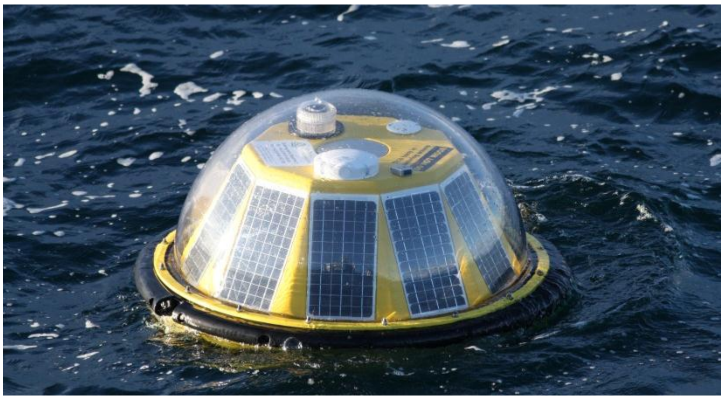

Figure 12 A wave buoy

4 Offshore construction and installation

4.1 The offshore construction and installation process could take place over a period of several years, and although it is often limited to favourable weather conditions, some activities could take place throughout the year.

Foundation installation

4.2 Foundations will be installed prior to the installation of the WTGs. Methods of installation vary depending upon the foundation type selected and may therefore require a range of installation vessel types.

Figure 13 Foundation installation

4.3 Techniques typically employed include:

- Pile driving;
- Seabed levelling (for gravity bases and suction caissons);
- Drilling;
- Connections such as grouting, swaging or bolting; and
- Pile connection activities (for multipiles and tripods).

Installation of WTGs, platforms and meteorological masts

4.4 WTGs, transition pieces (if required), met masts, substations, and accommodation platforms are commonly installed onto their foundation structures using one or more crane lifts from offshore barges, crane ships, or jack-up vessels.

4.5 WTGs for example, have been installed pre-assembled in a single crane lift, and also erected using a series of lifts to assemble multiple tower sections, the nacelle, and blades. These large construction vessels are often supported by support craft such as tugs, crew transfer vessels, and feeder barges and may be required either to stay on site, anchoring as required, or to transit to and from base ports.

Figure 14 Turbine assembly

Figure 15 Offshore substation assembly

Offshore cable installation

4.6 Inter-array and offshore export cables are typically installed from a cable laying vessel or barge, using either a multi-point anchoring or dynamic positioning system. The cable burial methodologies include:

- Direct burial during the laying campaign;
- Pre-trenching; and
- Post-lay burial

4.7 The two latter options have the advantage that the cable lay can be completed rapidly with the slower task of cable trenching being performed independently.

4.8 The different inter-array and export cabling burial techniques will vary depending on the location and the technology available at the time.

Nearshore export cable installation

4.9 Nearshore, where water depths of less than 10m prohibit the use of a cable installation vessel, the landfall section may need to be installed by a shallow draft barge. Operations in shallow water typically require the use of a multipoint anchor spread, whereby the barge is moved incrementally along the route by winches hauling against anchors.

Figure 16 Cable installation at the transition between nearshore and landfall

Installation of cable at the landfall

4.10 The landfall is the main interaction between the onshore and offshore works. A description of the landfall works is included in the onshore section (Section 4) of this document.

Offshore cable burial methodologies

4.11 The primary form of cable protection is to bury them below the seabed utilising either ploughing, mechanical trenching/cutting and/or jetting techniques as appropriate to the location. A detailed cable burial and protection assessment will be carried out to identify the most suitable burial depth in each area, including consideration of operating characteristics, sediment type and risk of damage to the cable from unstable sediments or external activities such as fishing or anchors.

Jet trenching

4.12 Jetting techniques involve injection of jet pressurised water into the seabed to fluidise a trench enabling the cables to sink safely into the seabed. Cable jetting devices include Injectors (typically slung from a cable barge), towed jetting sleds, tracked and thrusters-propelled Remotely Operated Vehicle (ROV) trenchers.

4.13 Injectors and towed sleds are generally used for shallow water operations where the cable is laid and simultaneously buried.

4.14 For deeper water work, jetting trenchers mounted on self-propelling ROVs are generally used; some are towed or coupled to a mechanical trenching device. Their manoeuvrability enables them to follow any cable route. Burial is generally limited to 1 to 2.5m because of the need to rely on cable sinkage, as opposed to the positive placement achieved by the enclosed tools of the towed sled and injector devices.

Figure 17 Triton T500 jetting tool [Perry Slingsby]

Mass flow excavation

4.15 Mass Flow Excavation (MFE) is sometimes used for remedial burial, particularly in coarse non-cohesive soils where jet trenchers have been unable to achieve sufficient burial. MFE utilises an impeller and duct system suspended from a vessel above the cable to direct a very high volume low pressure flow at the seabed. Material is fluidised and entrained in the flow causing excavation of a trench which (depending on seabed conditions) can be five or more meters wide and two to three meters deep. The advantage of the technique is that burial can be achieved where jet trenchers have under-performed. The disadvantages are slow progress, wide trench, and intensive survey.

Ploughing

4.16 Ploughing techniques are suitable for a large range of seabed conditions and soil types depending on the design and burial depths. Typical suitable soil types include sand, mud, soft to hard clay and boulders of up to about 250mm; although some ploughs have potential to be deployable in weak rock for burial depths of greater than 1.5m. Some ploughs comprise a combined jetting facility to improve performance in sand

4.17 There are advantages to ploughing, which includes greater cable burial depth, simultaneous lay and burial (in shallow waters) and the simplicity of the tooling. Disadvantages are some risk of damage to the cables during installation and less manoeuvrability than jetting ROVs.

Figure 18 MD-3 Plough [Tricomarine]

Mechanical trenching

4.18 In hard materials mechanical trenchers can be used to cut a trench using a chain cutter or a wheel cutter fitted with picks. Mechanical trenchers will typically employ a driven chain to break/move sediment. Chain cutters can trench up to approximately 3m, depending on vehicle power and seabed material. Wheel cutters are typically limited to burial depths of less than 1m, since the size of the wheel quickly becomes unmanageable at deeper depths. Such trenchers can bury cables in stiff clay to soft rock.

4.19 Mechanical trenching tools are capable of working in sands, clays and rock conditions, and are used for more onerous soil conditions.

4.20 Mechanical trenchers are normally configured for post lay burial. The cable is picked up by grabs or crane manipulators fitted to the vehicle and placed in the cable pathway. The chain cutter is started and lowered in to the seabed. The cable is laid or placed in to the cut trench. Due to the weight of the chain tool the trenchers are normally tracked, although for shallow water operations some sled mounted devices exist.

Figure 19 Rocksaw trencher [Global Marine]

Shallow water cable installation

4.21 It is anticipated that a separate system may be required to cover the inter-tidal and shallow water sections of the route. A typical system designed for such an application is the DPT5 (a high pressure shallow water jetting system, powered and controlled from a shallow water pumping barge). It is fitted with 2.5m jet swords and can trench in sand, silts and gravels.

Figure 20 DPT 5 [Sea Trench]

Remedial cable protection methodologies

4.22 In some cases additional protection may be required after the installation of a cable, for instance if sufficient burial depth is not achievable on the location. Typical cable protection measures include concrete mattressing or rock dumping, or remedial burial techniques (for instance mass flow excavation as described above).

Rock placement

4.23 Protection by rock placement involves installation of a rock ‘berm’ over the cable. A typical design cross section would be a trapezoidal berm 0.5m high, with 1.0m top width and side slopes of minimum 1:3 slope. Rock grade and density would be specified to ensure stability in the local current and wave climate. The rock is placed by a specialist vessel equipped with an ROV controlled fall pipe to ensure accurate rock placement. The correct berm dimensions are ensured by bathymetric surveys before and after rock placement.

4.24 Rock placement can also be used at cable crossings, to provide positive separation between cables and to protect the new cable after lay.

Figure 21 Cable protection by rock placement

Concrete mattressing

4.25 Concrete mattressing may be used as cable protection where sufficient burial depth is challenging or in cases where the cable is crossing of other infrastructure on the seabed.

Concrete mattressing for cable protection

4.26 For use as cable protection, the concrete mattresses are lowered down over the cables to provide a barrier against fishing gear or dropped anchors.

Concrete mattressing for crossings

4.27 In many cases separation is achieved by pre-installing concrete mattresses over the existing asset. Single or multiple layers can be used to achieve the required minimum separation. This is frequently the preferred media as the separation is guaranteed if the mattresses are correctly placed and the new cable laid on target.

4.28 As additional means of protection, a rigid concrete construction may be used for crossings. These can take many forms, and are sometimes simple saddles upon which a pipeline will rest over the crossing. Often used in conjunction with concrete mattresses.

Frond matts

4.29 Frond matts can be used in areas of high seabed currents. They work by trapping mobile sediments. Frond matts are also often used as remedial action to maintain the integrity of the crossing if not accounted for in the initial design.

Cable and pipeline crossings

4.30 Both inter-array and export cables may be required to cross existing pipelines or cables. The detailed methodology for the crossing of cables and pipelines by the export cables will be determined in collaboration with the owners of the infrastructure to be crossed. A number of techniques can be utilised, including:

- Pre-lay and post lay concrete mattresses;
- Pre-lay and post lay rock placement;
- Pre-lay steel structures; or
- Pre-constructed HDPE castings or other innovative approaches.

5 Offshore operation and maintenance

5.1 Once operational, the project will require regular inspections, service and maintenance throughout its lifetime. This will require a full time dedicated team of technicians and associated support staff. There are a number of approaches to the operation and maintenance (O&M) of the wind farm and the final solution will be determined following consideration of health and safety issues, transit duration, port location and facilities, weather downtime, WTG selection and the cost-benefit analysis of each option.

5.2 Given the distance of the project from shore, it is assumed that in addition to an onshore base at a suitable port, one or more offshore operations hubs will also be required. The offshore hub could be either a fixed platform at the site (standalone, or associated with one of the substation platforms), or a medium to large vessel which is able to travel between port and the project area. Transport to the offshore project elements could be by various means, including some combination of small, medium or large vessels, jack up vessels and helicopters.

Figure 22 A typical personnel transfer vessel docked with an offshore WTG

5.3 It is expected that as part of the O&M of the wind farm, large vessels may be used continually to support offshore activities – as offshore operations hubs, or otherwise. Therefore, it may be necessary to have a number of pre-installed permanent moorings at intervals around the project area to allow vessels to moor at the project site while work is ongoing.

Figure 23 An offshore support vessel

5.4 It is estimated that around ten of these moorings may be required per project, and that they will be likely to consist of a floating buoy with appropriate mooring systems (loops, pre-fixed cables, etc), secured via chains or cables to a system of anchors on the seabed.

5.5 Given the range of O&M options available, Forewind will ensure that these matters will be dealt with explicitly in the relevant topic sections of the EIA.

6 Offshore decommissioning and re-planting

6.1 Forewind is intending to apply to the Crown Estate for a lease for up to 50 years for the wind farm sites. The design life of individual components of the projects will vary, however for most offshore WTG structures it is around 20 years and therefore it is expected that around this time consideration will be given to replanting. Re-planting consists of replacing some or all components with new parts, to a partly or wholly new project design. If this were to take place, then the necessary consents and licenses would need to be secured at that time.

6.2 At the end of the project life, it will have to be decommissioned. This is a condition of The Crown Estate lease for the site, as well as a statutory requirement through the provisions of the Energy Act 2004.

6.3 For the purposes of the EIA the decommissioning of the wind farm would likely be the reverse of the construction process with some exceptions. Piled foundations would likely be removed to just below seabed with due consideration made of likely changes in seabed level. Currently there is no statutory requirement for decommissioned cables to be removed and it is possible that these will be left in situ once the wind farm is decommissioned. It is expected that decommissioning will require similar vessels to construction and will take a similar period of time.

7 The Onshore Project Components

Overview of the onshore project components

7.1 The main onshore components of the Dogger Bank Teesside projects include -

- Onshore landfall works - The landfall is the transition between the offshore export cable systems and the onshore underground cable systems. It comprises buried landfall cables and buried joints. The landfall cables may be different to the offshore export cables so it is usual to refer to this section as landfall cable to distinguish it from the onshore underground cables and offshore export cables;
- Onshore HVDC cable systems - The HVDC cable systems will connect the landfall cables to the onshore converter stations. They will be buried underground and will comprise several component parts that may be installed directly in cable trenches or in ducts;
- Onshore converter stations - The converter stations will convert the HVDC power being exported from the offshore wind farms to HVAC, prior to connection to the National Grid substation(s); and
- Onshore HVAC cable systems - The HVAC cable systems will connect the onshore converter stations to the existing National Grid substation(s). They will be a buried underground and will comprise of similar components to the HVDC cable systems.

7.2 In addition, some works will be required to the national grid electricity transmission network to allow connection of the Dogger Bank Teesside projects. Consenting, constructing, operating and decommissioning these works will be the responsibility of National Grid.

7.3 A description of the main components and the associated installation methods is included in the sections below.

8 Landfall works

8.1 The point at which the offshore export cable systems join the onshore cable systems is called the landfall. Forewind has identified a preferred landfall area for Dogger Bank Teesside on the Teesside coastline between Redcar and Marske–on–the-Sea[4].

8.2 Up to four separate landfalls may be required and these may all be located within the preferred landfall area or split over more than one landfall area. A photograph showing a typical shoreline between Redcar and Marske-on-the-Sea is shown in Figure 24. The landfall cables will be buried under this shoreline.

Figure 24 Typical shoreline at Forewind's preferred landfall area on the Teesside coastline

Landfall installation methodology

8.3 At the landfall, the offshore export cables will be buried under the low tide waterline and jointed to the landfall cable section (if separate landfall cable

[4] For more information on the landfall selection process, please refer to Dogger Bank Teesside PEI1 Appendix C – Landfall and Converter Station Site Selection Report

sections are used). The landfall cables or offshore export cables will be buried beneath the beach and low lying cliffs, and will join the underground onshore cables at buried joint bays. An example layout is shown in Figure 25.

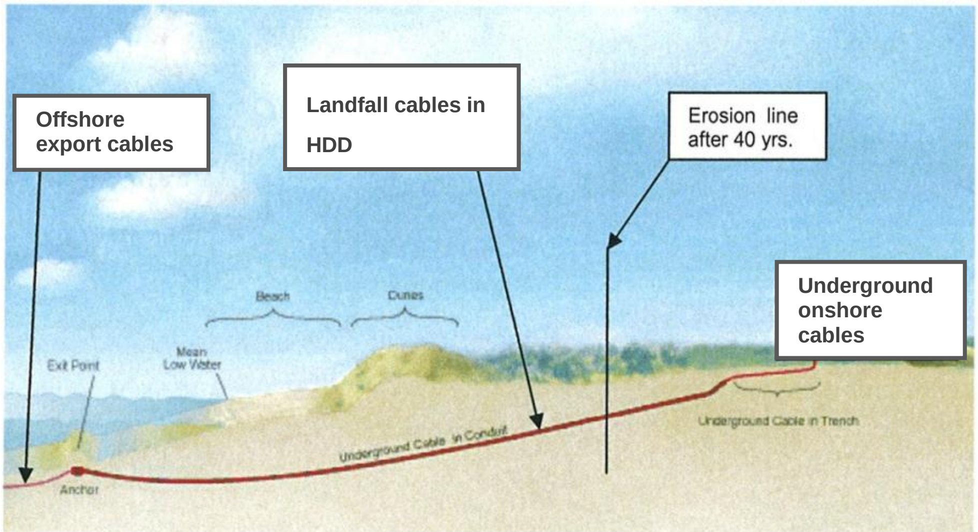

Figure 25 Typical landfall cable arrangement (not to scale) (Courtesy ABB)

8.4 Coastal erosion rates on the Teesside coastline are typically 20m in 50 years in some places so precautions will be taken to ensure that the cables do not become exposed during the lifetime of the projects. Detailed assessment will determine how deep the cables must be buried and how far back from the current coastline the joint bay needs to be located to account for coastal erosion. It is expected that the joint bay may be over 100m inland as illustrated in Figure 25, but please note that this is not to scale.

8.5 The landfall cables will be buried below the shoreline. There are two main techniques which can be utilised; open trenching or horizontal directional drilling (HDD). In order to minimise the disruption on the shoreline caused by open trenching the preferred construction method is to use HDD techniques

8.6 A typical installation by HDD involves drilling a pilot hole from behind the low lying cliff face down to the beach, reaming (to make the hole bigger), pulling a conduit pipe through the reamed hole, then pulling the landfall cables through the conduit. It is not usual to pull more than one cable through a conduit, so two separate HDDs will be required for each HVDC cable system. The figure below is a schematic of the scenario where the HDD is long enough to avoid the need for a joint on the beach.

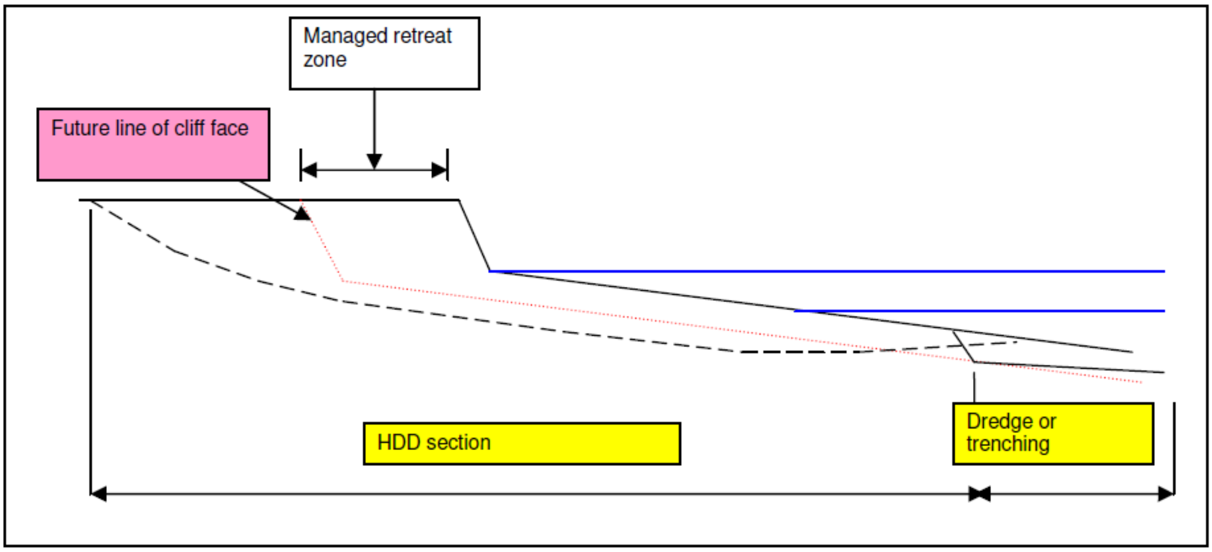

Figure 26 Schematic diagram to show a typical HDD through an eroding coastline (Courtesy JP Kenny)

8.7 If the HDD is not long enough to cross under the whole length of the beach to the incoming offshore export cable, an extra section of offshore export cable will be jointed in. The joints will be buried beneath the beach and the extra section of offshore export cable will be buried under the remaining shoreline from the joint to the HDD using the open trenching method. This would require a sheet piled trench on the beach to hold back the sea water during jointing and trenching. A photograph showing an example of a sheet piled trench is shown below.

Figure 27 Example of a sheet piled trench being installed on a beach (Courtesy Intertek METOC)

8.8 A temporary construction area of approximately 0.5 hectares (ha) will be required to contain the drilling equipment for the HDDs. This will be fenced off and not accessible to the public for health and safety reasons. Some noise will be generated by the diesel generators used to power the drill and flood lights may be required in poor light conditions.

Figure 28 Photograph of typical HDD equipment (Courtesy JP Kenny)

8.9 Once the landfall cables have been pulled ashore through the HDD, they will be connected to the onshore cables in a buried joint bay.

Installation phasing and programme

8.10 Since multiple offshore export cable systems will be used to export the electricity generated by Dogger Bank Teesside, it is possible that the landfall works may not be completed all at once, but in phases, with the HDD equipment removed from the site after each phase. The timing of the landfall works will be dependent upon any seasonal restrictions required by the EIA, landowner negotiations and the programme of works on the offshore export cables and onshore underground cables.

8.11 Landfall works would normally take place in spring or summer, and the winter is feasible providing the weather was not restrictive.

Post-installation activities

8.12 The ground above the joint bay will be reinstated on completion of the jointing. There will be no permanent above ground structure at the landfall.

Operation and maintenance

8.13 During operation of the wind farms there may be a need to access the landfall joint bay for emergency repair purposes, but this is expected to be a rare occurrence.

Decommissioning

8.14 Requirements for decommissioning of the cables at the landfall will be agreed with the relevant statutory organisations.

9 Onshore HVDC underground cables

Introduction

9.1 The onshore HVDC cable systems will transmit the generated electricity from the landfall on the Teesside coastline, to the converter stations near the relevant National Grid substation(s). The onshore cable systems will be buried underground for the entire length of the route.

9.2 Forewind has ruled out an overhead line connection for a number of reasons, which include the landscape and visual impact.

Onshore HVDC cable system details

9.3 The capacity of the cable system and specific cables to be used will be subject to detailed design analysis, in consultation with specialist cable manufacturers; however Forewind has based their assessments so far on the following details:

- An HVDC cable system requires a pair of cables; one positive cable and one negative cable. In addition the cable system will include any fibre optic cables required for communication systems.

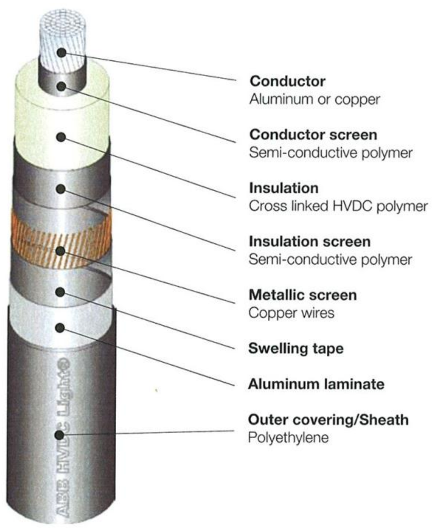

Figure 29 A cutaway view of a typical onshore HVDC cable (Courtesy ABB)

- The positive and negative cables and the fibre optic cables can be laid next to each other in one trench approximately 1.5m deep and 1.5m wide. The cables can be laid directly into the trench or in ducts.

- The cable systems for each project have to be separated from each other by a short distance so up to four trenches may be required, as shown in Figure 30. The space between trenches is used to store spoil and for haul roads.
- The cable systems will be accommodated either within a single cable route corridor or in a number of different corridors from the landfalls to the converter stations. This decision will be dependent upon the outcome of technical assessments, the EIA and construction timing considerations.

Figure 30 An indicative layout of cable trenches, haul roads and spoil heaps for four projects in a single cable route

- It is possible that not all of the cable systems will be installed at once. Therefore, Forewind proposes to allow for the option of installing ancillary underground ducting which could be installed adjacent to, and at the same time as, a cable system. The ducting would facilitate retrospective pull-through of cables at a later date and minimise necessary cable installation works and disruption during this later cable installation.

Typical cable installation methods

9.4 A range of cable installation techniques are available, including cable ploughing (lower shore area), open cut trenching, coffer dam, and tunnelling or boring techniques (such as directional drilling technology). Forewind will consult stakeholders and use the results of surveys and assessments to determine the appropriate techniques for installation along the route.

9.5 It is likely that open cut trenching will be used to install the majority of the cable in relatively unconstrained areas and HDD may be considered as an alternative methodology cross significant environmental and physical features such as main rivers, canals, main roads and railways. A description of HDD is included in the landfall section above and a description of the key elements of open cut trenching is provided below.

9.6 Once construction is underway, trenches will be cut. In order to keep the cable trench clean and safe it is usual practice to shore up the trench. Shoring may be provided in a number of ways. For example, traditional double sided close timbered shoring, hydraulic shoring or box shoring. Unless the ground conditions are poor, it is not usual for the trench to require shoring with timber when ducts are installed.

Figure 31 Example of close timbered trench (Courtesy Prysmian)

9.7 The cables will be laid in sections typically up to 1km long. Sections will be connected together using cable joints which will be buried. A power supply would be required in the joint area during construction to operate equipment and lighting and in the winter to provide heating. Silenced generators would be positioned at joint bays where noise pollution may cause a disturbance.

9.8 The area around the joint bay will be prepared to accept the cable drums onto a hard standing. The drums will be delivered to site by low loader or cable trailer. A typical low load trailer is 18m long and has an unladen weight of circa 28 tonnes.

Figure 32 Cable drum and trailer (Courtesy Prysmian)

9.9 Transporting the drum over motorways and major roads should not present any problems and the low loader width is such that a Police escort should not be necessary. Transporting the drum through country villages and along country lanes may require the temporary removal of street furniture, overhanging tree pruning, bridge strengthening, possible road closures and other road safety and access measures.

9.10 If the cables are to be buried directly in the trench, the trench floor will be cleared and, if necessary, prepared with cement bound sand (CBS). The cables will then be winched into place and then CBS delivered by mixer will be tamped into position around and over the cables. Cover tiles containing a warning are then installed above the cables. At this point the timber shuttering is removed and the trench is further backfilled with previously excavated material. The backfill is compacted and includes warning tapes installed 150mm above the cover tiles.

Figure 33 Delivery of cement bound sand (Courtesy Prysmian)

9.11 If ancilliary underground ducting is to be installed, the ducts would be installed in trenches from joint bay to joint bay. The cables can then be pulled through the buried ducts with the aid of a water based lubricant at a later date, if required.

9.12 The normal construction working width of the cable route for a single project is expected to be approximately 20m. This includes a pair of HVDC cables (one cable system) installed in a single cable trench and the required spacing, the haul road required for construction traffic, and soil storage areas. Where an HDD is used, an additional area of up to 0.4ha may be required. This working area will be enclosed within security fencing.

9.13 Therefore, the total construction working width for four projects from the landfall to the converter substation locations may be up to 4 x 20m. These could be in a single route approximately 80m wide or in four separate cable routes each approximately 20m wide.

9.14 It is expected that approximately two temporary construction compounds will be needed for storage of cables and equipment, accommodation and site offices per project. Therefore there may be up to eight temporary construction compounds in total. Each of these compounds will require approximately 1.5ha and will be located at appropriate points along the cable route. These compounds will have restricted access and will be enclosed within security fencing. In addition, a number of smaller temporary construction areas of less than 0.2ha may be required for jointing cables and for health, safety and welfare purposes.

Timescales and programme

9.15 The duration of the excavation, cable installation and backfilling works will depend on the nature of the ground e.g. rock content, dewatering content. For a cable route of this length (circa 5-10km) and assuming work may be restricted to summer months and drier winter months, construction will take approximately one year per project.

9.16 Where ducts are installed in separate trenches for future cable installation then there would be an additional cable installation campaign to pull the cables through the ducts at a later date, if required.

Post-installation activities

9.17 Following installation of all cables and joints in a section, the construction working width would be cleared and reinstated.

9.18 Where necessary this reinstatement may include replanting of hedgerows, replacement of fences, removal of temporary land drains and settlement ponds, reinstatement of permanent land drains and the like.

9.19 The following pictures show a typical HV cable route after topsoil reinstatement and the same location 18 months after.

Figure 34 Cable swathe after topsoil reinstatement (left) and after 18 months (right) (Courtesy Prysmian)

Operation and maintenance

9.20 A cable system design life of circa 40 years is provided by manufacturers. Occasional access may be required to the cable for fault finding and repair purposes.

Decommissioning

9.21 There is currently no statutory requirement for decommissioned cables to be removed and it is likely that removal of the cables would bring about further environmental impacts. Therefore, at present it is proposed that the cables will be left in-situ but this will be reviewed over the design life of the project.

10 Onshore converter stations

Introduction

10.1 There will be up to four converter stations, as described below. These will convert the HVDC export power to HVAC prior to connection to the relevant National Grid substation(s). The converter stations represent the main permanent and visible aspects of the onshore works.

10.2 The specific details of the converter stations will be subject to detailed engineering design. Due to the fact that converter station technology is very new, it is difficult to predict what the standard capacity of converter stations will be at the time of construction. The converter stations will be co-located wherever possible.

Converter station details

10.3 Each converter station will include:

- Rigid aluminium DC and AC current connectors and transformers, which will be outdoors; and
- A valve hall, which is a large building that houses electronic devices that convert the power from DC to AC and includes a control room.

10.4 The valve halls will be up to 30m tall and will be steel framed buildings with cladding. The colour and external materials will be agreed with the local authority. Lightning conductors will be installed, each of which will be a slim metal rod up to 40m in height. A photograph of a typical converter station is shown below.

Figure 35 A typical DC-AC Converter Station at Murraylink, Victoria, South Australia (220MW)

10.5 Each converter station will include offices and welfare facilities for the maintenance staff and visitors. An area of hard standing will be set aside for car parking and a tarmac road will run around the perimeter of the site. The site would be enclosed within security fencing.

10.6 An indicative example of a single 1GW converter station is shown below in outline:

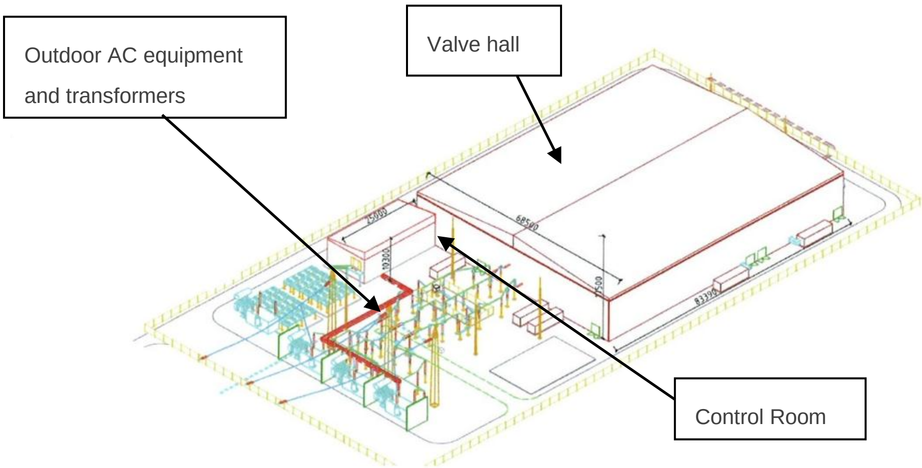

Figure 36 Indicative drawing to show the general arrangement of a converter station (Courtesy Siemens)

10.7 The footprint of each 1GW converter station based on such a design and including on site roads is approximately 2ha. Landscaping would be undertaken as required and it is envisaged that this may require an additional area of up to 2ha. Drainage may require an additional 0.5ha. Each converter station would be serviced by a tarmac road of up to 6m in width. In addition, up to 1ha may be required on a temporary basis during construction.

10.8 Therefore, Forewind has determined that a single 1GW converter station could require a permanent footprint of up to 4.5ha, taking into account the land needed for the converter station itself, necessary landscaping and drainage works. In addition, 1ha would be required on a temporary basis for construction works.

10.9 Forewind has decided to co-locate converter stations for two or more projects (rather than develop four separate sites for the converter stations), so the site selection process allows for either:

- Two co-located 1GW converter stations; or
- Four co-located 1GW converter stations.

10.10 Therefore, Forewind is ultimately seeking either two sites of 9ha each (to accommodate converter stations for two projects), or a single site of up to 18ha (to accommodate converter stations for all four projects). In addition, up to 4ha would be needed on a temporary basis during construction.

Typical construction methods

10.11 The external construction methods employed would be those typical of a large steel framed building with cladding. The base would typically be formed from a large concrete raft and will be designed along with the rest of the site in consultation with stakeholders, particularly with regard to water drainage and flooding.

Post construction activities

10.12 At this early stage in the consenting process examples of generic mitigation are provided for information purposes. Specific requirements will be agreed with the local authority and other stakeholders at a later stage in the consenting process.

10.13 Mitigation will be provided for the landscape and visual impact where appropriate, and measures may include strengthening existing hedgerows, and planting tree belts and woodland plantations.

10.14 The drainage requirements of the converter station site(s) will also be assessed. It may be necessary to create attenuation ponds and consider other drainage methods post construction. These would be agreed with stakeholders as appropriate.

10.15 A detailed noise assessment will be carried out at the EIA and design stage, and is a key factor in siting, design and layout of the plant. There are several options for mitigating operational noise, and any additional mitigating requirements will be installed post-construction. These can include the use of enclosures, screens, baffles and sound barriers. Landscaping may also mitigate noise arising from the converter stations.

Timescales and programme

10.16 Construction of a typical converter station (including the valve hall and outdoor equipment) is expected to take up to three years. If multiple sites are required, the timescales may be extended depending on the phasing of the works.

Operation and maintenance

10.17 The converter stations will generally be unmanned; however access will be required throughout the lifetime of the projects for monitoring and planned maintenance purposes. Vehicle movements are likely to be infrequent.

Decommissioning

10.18 The site will be restored in accordance with the Decommissioning Programme, which will be agreed with the local planning authority.

11 Onshore HVAC underground cables

Introduction

11.1 Once the power has been converted into HVAC (400kV as stipulated by National Grid) at the onshore converter stations, the power will be transmitted to the relevant National Grid substation(s) by underground HVAC cable systems.

11.2 Forewind has ruled out the option of connecting the converter stations to the National Grid substation(s) by overhead line. A three phase HVAC underground cable system is technically preferred and will also be less intrusive.

Onshore HVAC cable system details

11.3 The cable system from each converter station would comprise of a three phase cable i.e. three single 400kV cables and a fibre optic communications cable installed in a trench. A typical 400kV cable is shown below.

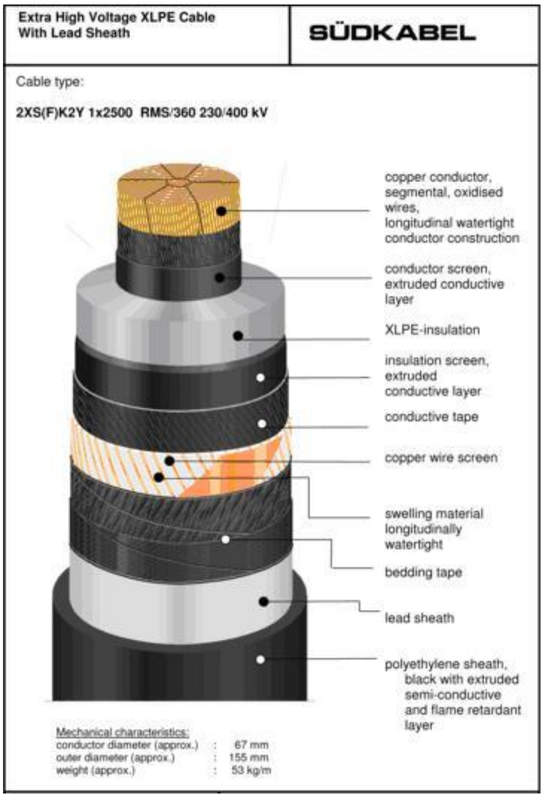

Figure 37 A typical 400kV HVAC cable

Typical installation methods

11.4 The HVAC cable is very similar to the HVDC cable and construction methods would be identical to that for the HVDC onshore cable i.e. buried directly in a trench or duct. The trench for each HVAC cable system would be wider (up to 2m wide) than the trench for the HVDC cable system to allow for three cables rather than two. It is anticipated the distance from the converter stations to the National Grid substation(s) would be as short as possible to minimise the length of the HVAC cable section.

Timescales and programme

11.5 Since the HVAC cable system is likely to be relatively short, the work would be likely to be carried out in the summer and phased in with the construction of the converter stations.

Post construction activities

11.6 Following installation of all cables and any joints in this short section, the construction working width would be cleared and reinstated.

11.7 Where necessary this reinstatement may include replanting of hedgerows, replacement of fences, removal of temporary land drains and settlement ponds, and reinstatement of permanent land drains and the like.

Operation and maintenance

11.8 A cable system design life of approximately 40 years is provided by manufacturers. Occasional access may be required to the cable for fault finding purposes.

Decommissioning

11.9 There is currently no statutory requirement for decommissioned cables to be removed and it is likely that removal of the cables would bring about further environmental impacts. Therefore, at present it is proposed that the cables will be left in-situ but this will be reviewed over the design life of the project.

12 National Grid's substations

12.1 National Grid is responsible for acquiring the necessary consents and undertaking any work at the substation(s) to facilitate connection of Dogger Bank Teesside projects. These works are referred to as "Enabling Actions". The Enabling Actions will be considered in the environmental impact assessment work for Dogger Bank Teesside.

12.2 National Grid is at present unable to confirm the precise details of the Enabling Actions. It is expected that they will be limited to works around the existing Lackenby 400kV substation footprint. However the connection substation for the latter projects has yet to be determined, and may require the construction of a new 400kV substation in the Teesside area, at a location that has yet to be determined.

12.3 Forewind expects to be able to include more details of the Enabling Actions in the next phase of consultation on Dogger Bank Teesside, prior to the application(s) being submitted.

For more information

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