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Anholt Offshore Wind Farm

Project Description

January 2010

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Project Description

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Table of contents

1. Introduction

This report presents the details of the proposed development. The construction, operation, maintenance and decommissioning phases are described in terms of likely component options and their installation and use. The description includes the offshore part of the development.

2. Site Location

The proposed development site is located between the headland Djursland of Jutland and the island Anholt.

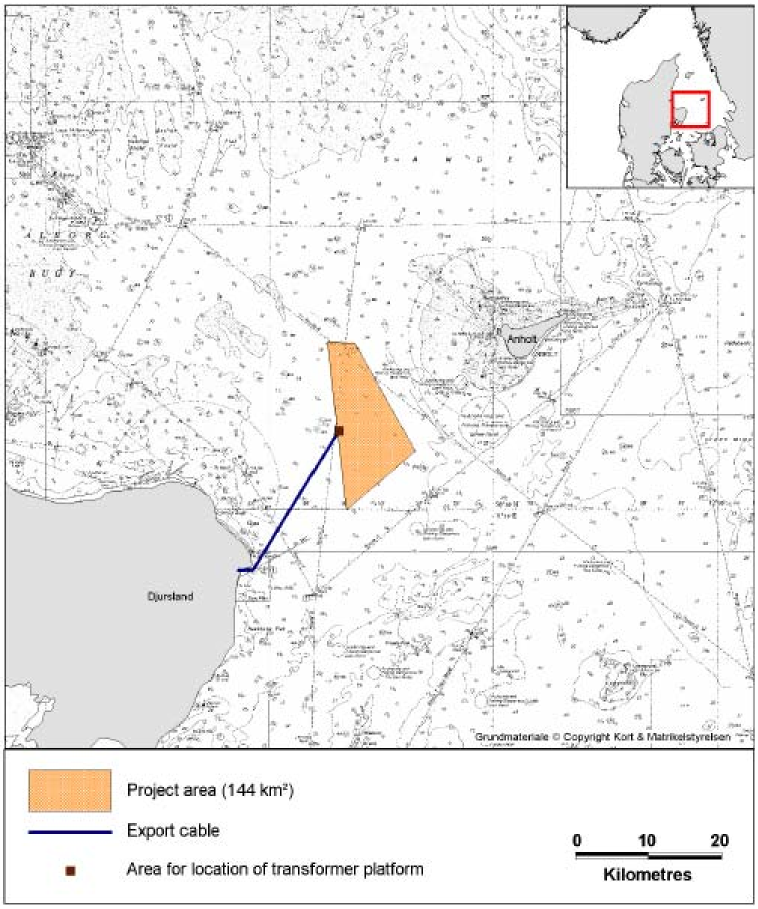

Figure 2-1 Site location.

An area of 88 km^2 is allocated to the development and shall include the wind turbines and all wind farm infrastructures excluding turbine-radials and the offshore transformer platform. The allocated area shall be located within the larger project area of 144km^2 given by following parameter coordinates:

Corner	**Projection UTM32N** Datum Euref89 (WGS84)		**Geographical coordinates** Datum Euref89 (WGS84)	
	Easting (m)	Northing (m)	Latitude (deg/dec.min)	Longitude (deg/dec.min)
1	630 306.9	6 286 386.4	56 42.199974	11 07.700017
2	634 010.9	6 286 386.4	56 42.137118	11 11.326957
3	642 867.4	6 272 079.4	56 34.274013	11 19.523145
4	633 573.2	6 263 840.2	56 30.000011	11 10.199994

Table 2-1: Coordinates of wind farm area

The offshore transformer platform is planned within a 100x100m area in the western part of the project area. The coordinates to corners of the area are:

Corner	**Projection UTM32N** Datum Euref89 (WGS84)		**Geographical coordinates** Datum Euref89 (WGS84)	
	Easting (m)	Northing (m)	Latitude (deg/dec.min)	Longitude (deg/dec.min)
1	632 160	6 274 518	56 35.7757	11 35.7757
2	632 260	6 274 518	56 35.7740	11 35.7740
3	632 260	6 274 418	56 35.7202	11 35.7202
4	632 160	6 274 418	56 35.7218	11 35.7218

Table 2-2: Coordinates of transformer platform area

In addition, a maximum of 2 export cables are anticipated to be required in order to transmit the generated electricity to shore. The landfall will be allocated at the industrial area Grenå North.

Landfall	**Projection UTM32N** Datum Euref89 (WGS84)		**Geographical coordinates** Datum Euref89 (WGS84)	
	Easting (m)	Northing (m)	Latitude (deg/dec.min)	Longitude (deg/dec.min)
Grenå Nord	618 956	6 255 169	56 25.5637	10 55.7245

Table 2-3: Coordinates of cable landfall

3. Physical Characteristics

3.1 Metocean Characteristics

The location of the proposed Anholt Offshore Wind Farm has the following main characteristics:

Parameter	Value
Overall average wind speed	6.3 m/s
Water depth range	15-20 m
Extreme high water (MSL)	1.4-1.7 m
Extreme low water (MSL)	-0.8- -0.9 m
Extreme wave height	3.6-4.1 m
Max wave height	5.3-5.7 m
Extreme current	0.6-0.75 m/s

Table 3-1: Metocean data

Detailed metocean data is given in ref. /5/

3.2 Geological / Geotechnical Characteristics

A geophysical survey of the wind farm area including the cable corridor has been conducted from March to May 2009, refs. /1/ and /2/.

A geotechnical boring campaign has been conducted from May to June 2009, refs. /3/ and /4/, to document the dominating types of geological formations encountered by the geophysical survey, and at the same time to establish geotechnical parameters of the various geological formations.

The top formation at seabed or just below sea bed constitutes of mainly Holocene sand. The unit is 0-7m thick and in most of the survey area less than 2m thick.

The Holocene sand is overlying a late glacial unit, which is filling in depressions in the underlying earlier glacial unit. The largest infilling basin is found in northern and north-eastern part of the survey area, constituting a 2-5km wide basin approximately 10km long. The thickness is up to 38m.

The glacial unit is found all over the survey area. In the southern part the glacial deposits crop out at the sea floor, but otherwise the unit is encountered immediately below the late glacial deposits.

The pre-quaternary unit is observed in two overall areas – one in a 3 by 3km area most northerly and another in the south-westerly part of the area. The top of the unit is found at depths of 25 – 30m below seabed.

The major soil types encountered in the various units are:

Unit / soil type	Characteristics
Holocene Sand	Poorly graded sand, sometimes organic or clayey
Late glacial sand and gravel	Poorly graded to well graded sand and/or gravel, sometimes small organic content
Late glacial clay	Medium to highly plastic clay, at places with small organic content
Glacial till	Well graded sandy clay or clayey sand
Pre-quaternary claystone	Weakly indurated calcareous, slightly organic claystone

Table 3-2: Major soil type

4. Offshore Components and Their Installation

The components of the wind farm will not be determined until later in the project programme, after offers have been received from nominated developers. Therefore a description of the likely minimum and maximum components and their installation is provided in this document, together with any alternatives and corresponding methods of installation. The environmental assessment indicates a worst case impact for various parts of the project.

4.1 Wind Turbines

4.1.1 Description

The maximum rated capacity of the wind farm is limited to 400MW. The farm will feature from 80 to 174 turbines depending on the rated energy of the selected turbines corresponding to the range of 2.3 to 5.0MW. There is a possibility that more than one model of the turbine will be installed due to the rapid development of the wind turbine industry and a multi-year construction programme.

Figure 4-1: View of a wind farm

The wind turbine will comprise tubular towers and three blades attached to a nacelle housing containing the generator, gearbox and other operating equipment. Blades will turn clockwise, when viewed from the windward direction. The wind turbine will appear as a homogenous structure. The unit transformer will be located either at tower base or at top of the tower depending on the type of selected turbine.

The wind turbines will begin generating power when the wind speed at hub height is between 2 and 5m/s. The turbine power output increases with increasing wind speed and the wind turbines typically achieve their rated output at wind speeds between 12 and 15m/s at hub height. The design of the turbines ensures fail safe operation, such that if the average wind speed exceeds 25 to 30m/s for extended periods, the turbines shut down automatically.

Dimensions Preliminary dimensions of the turbines are not expected to exceed a maximum tip height of 160m above mean sea level for the largest turbine size (5.0MW).

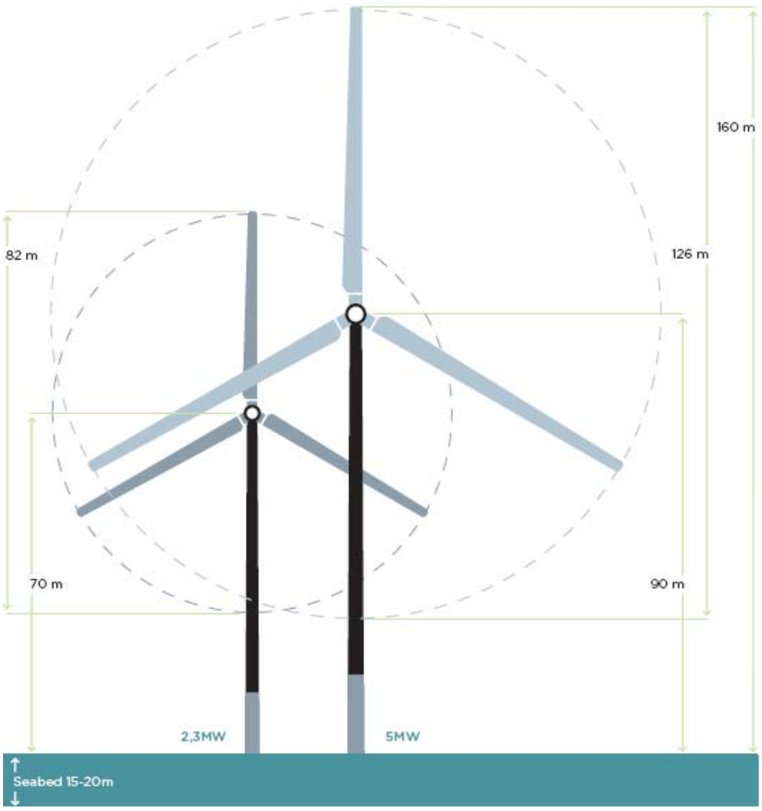

Figure 4-2: Turbine dimensions.

Outline properties of present day turbines are shown in the Table below. Included is also data from Horns Rev 2 and Rødsand 2.

Turbine Rated Capacity (MW)	Rotor Diameter (m)	Hub Height above MSL (m)	Air Gap at MSL (m)	Comments
2.3	82	70		
2.3 var	93	75		
3.0	90	75		
3.6	104	80		
5.0/6.0	126	90		
2.3	91	68	23	Horns Rev 2
2.3	90	68.5	22.6	Rødsand 2

Table 4-1: Turbine dimensions

The air gap between mean sea level (MSL) and the lower tip of the blades will be determined based on the actual project; however a minimum of approximately 23m above MSL is expected as also used at Horns Rev 2 and Rødsand 2.

4.1.2 Oils and Fluids

Each wind turbine contains lubricants and hydraulic oils, and typical quantities are shown in the table below. The wind turbine designs provide for capturing a lubricant spill from a component.

Fluid	Approximate quantity
Gearbox oil (mineral oil)	500 – 1000 litres
Hydraulic oil	200 - 300 litres
Yaw/pitch motor oil	20 - 100 litres
Transformer oil	2,000 – 3,000 litres

Table 4-2: Lubricants and oils in a turbine

4.1.3 Colour

A typical colour of the turbine towers and blades will be grey (RAL 1035 or similar), whereas the base of the tower will be yellow.

4.1.4 Lighting and Marking

The wind turbines will exhibit distinguishing markings visible for aircrafts and vessels in accordance with recommendation by Danish Civil Aviation Administration (Statens Luftfartsvæsen) and Danish Maritime Safety Administration (Farvandsvæsnet).

Aviation markings will be agreed with Statens Luftfartsvæsen. The general guidelines are, that turbines located at corners and along the periphery of the wind farm, where the distance between corners exceed 5km will be equipped with white flashing lights (2.000 candela as a minimum). All other turbines will be equipped with red light of low intensity (10 candela as a minimum). In case the turbines exceed a height of 150m, they should all be equipped with white flashing lights.

There is no common practice for safety zones at Danish offshore wind farms since the need for protection varies. At Nysted, 'restriction in practices'-zones have been applied for the entire park for trawling, aggregate extraction and dredging or anchoring (for non-project vessels). Safety zones may be applied for Anholt Offshore Wind Farm area or parts hereof. For all turbines a prohibited entry zone of minimum 50m radius is foreseen for non-project vessels.

In the event that a permanent safety zone will be established the marking will, as a minimum, include a number of yellow lanterns placed on the wind tower turbines. The lanterns will have flashing lights and an effective reach of at least 5 nautical miles compared to the recommendations by IALA (International Association of Lighthouse Authorities). The establishment of safety zones at Anholt Offshore Wind Farm are subject to application to Søfartsstyrelsen. The exact specifications of the marking of the safety zones will be determined by Farvandsvæsenet.

4.1.5 Noise Emission

There are two types of noise associated with wind turbines; aerodynamic and mechanical noise. Aerodynamic noise is broad-band in nature, relatively unobtrusive and is strongly influenced by incident conditions, wind speed and turbulence intensity. An operational Sound Power Level is expected in the order of 110dB(A), but will depend on the selected type of turbine.

Mechanical noise is generated by components inside the turbine nacelle and can be radiated by the shell of the nacelle, blades and the tower structure. Such noise emissions are not considered significant for the present generation of turbines to be considered for the Anholt Offshore Wind Farm.

Noise calculation on selected area on land using the WindPro software for modelling of wind parks shows, that noise levels are well below allowed limits.

4.1.6 Installation

The wind turbine components will either be stored at an adjacent port and transported to site by support barge or the installation vessel itself, or transported directly from the manufacturer to the wind farm site by barge or by the installation vessel. The wind turbine will typically be installed using multiple lifts.

Although offshore contractors have varying construction techniques, the installation of the wind turbines will typically require one or more jack-up barges. These vessels stand on the seabed and create a stable lifting platform by lifting themselves out of the water. The area of seabed taken by the feets of a vessel is approximately 350m^2 (in total), with leg penetrations of up to 2 to 15m (depending on seabed properties). These holes will be left to in-fill naturally.

Figure 4-3 Port facilities Burbo Banks (Courtesy: Siemens)

Figure 4-4 Installation of tower and nacelle Lillgrund (Courtesy: A2SEA)

It is expected that turbines will be installed at a rate of one every one to two days. The works would be planned for 24 hours per day, with lighting of barges at night, and accommodation for crew on board. Following installation and grid connection, the wind turbines are commissioned and are available to generate electricity.

4.2 Foundations

The wind turbines will be supported on foundations fixed to the seabed. It is likely that the foundations for the proposed Anholt Offshore Wind Farm will comprise one of the following options outlined below:

- driven steel monopile
- concrete gravity base

4.2.1 Driven Steel Monopile

Description

The monopile has been used at a large number of wind farms in the UK and in Denmark on e.g. Horns Rev 1 and Horns Rev 2.

This solution comprises driving a hollow steel pile into the seabed. The ability to drive piles to the required depth may be limited by deep layers of coarse gravel or boulders, and in these circumstances the obstruction may be drilled out. A transition piece is installed to make the connection with the wind turbine tower. This transition piece is generally fabricated from steel, and is subsequently attached to the pile head using grout. The grouting process is discussed later in Section 4.2.3.

Figure 4-5: Typical monopile foundation (Courtesy: Ramboll)

Dimensions

The dimensions of the monopile will be specific to the particular location at which the monopile is to be installed. The results of some very preliminary monopile and transition piece design for
the proposed Anholt Wind Farm, are presented below:

	Smaller turbine	Larger turbine
MONOPILE		
Outer diameter	Up to 5 m	Up to 6 m
Pile length	Up to 30 m	Up to 35 m
Weight	Up to 250 t	Up to 350 t
Ground penetration (below mud line)	Up to 25 m	Up to 30 m
Total weight 174/80 turbines	Up to 42,500 t	Up to 28,000 t
TRANSITION PIECE		
Length	Up to 25 m	Up to 25 m
Outer diameter	Up to 5 m	Up to 6 m
Weight	Up to 150 t	Up to 225 t
Volume of grout per unit	Up to 20 t	Up to 25 t
Total weight 174/80 turbines	Up to 30,000 t	Up to 20,000

Table 4-3: Dimensions of monopile foundation

Installation

The construction aspects of the driven monopile support structure option are discussed below.

Seabed Preparation

The monopile concept is not expected to require any preparation, but some removal of seabed obstructions may be necessary.

Installation Sequence

The installation of the driven monopile will take place from either a jack-up platform or floating vessel, equipped with 1-2 mounted marine cranes, a piling frame, and pile tilting equipment. In addition, a small drilling spread, may be adopted if driving difficulties are experienced. A support jack-up barge, support barge, tug, safety vessel and personnel transfer vessel may also be required.

Figure 4-6: Driving of Monopile Burbo Banks (Courtesy: MT Højgaard)

The installation sequence, which can vary according to pile size and vessel characteristics, is typically as follows:

- Load pile (or piles) onto support barge at the onshore support base, sea-fasten, and transport to site. Alternatively tow floated piles to the site from the manufacturing base
- Anchor handling (installation of anchors) at the turbine location (if required)
- Jack-up barge arrives at the installation location, extends the lifting jacks and performs stability tests prior to lifting
- Pile is transferred from the barge to the jack-up and then lifted into a vertical position
- The pile is then driven until target penetration is achieved
- Remove hammer
- Installation of transition piece
- Jack-up barge moves to next installation location to meet barge with next pile
- Anchor handling, removal and re-deployment of anchors (if required)

Driving Time

The expected time for driving each pile is between 4 and 6 hours. An optimistic estimate would see one pile installed and transition grouted at the rate of one per day.

Noise Emissions

The underwater noise generated by pile driving during installation has been measured and assessed during construction of wind farms in Denmark, Sweden and England, refs. /4/ and /5/. The noise will depend among other things of the pile diameter. An indicative source level of the pile driving operation would be in the range of 200 to 250dB re 1Pa @ 1meter.

The Grouting Process
Grouting is used to fix transition pieces to the piled support structure. Grout is a cement based product, used extensively for pile grouting operations worldwide. The grout used for the proposed Anholt Offshore Wind Farm would conform to the relevant environmental standards. The grout will either be mixed in large tanks aboard the jack-up platform, or mixed ashore and transported to site.

The grout is likely to be pumped through a series of grout tubes previously installed in the pile, so that the grout is introduced directly between the pile and the walls of the transition piece.

Methods will be adopted to ensure that the release of grout into the surrounding environment is minimised, however some grout may be released during the process. A worst-case conservative estimate of 5%, (up to between 100 and 174 t for the entire project) has been assumed.

4.2.2 Gravity Base

Description
These structures rely on their mass including ballast to withstand the loads generated by the offshore environment and the wind turbine.

The gravity base concept has been used successfully at operating wind farms such as Middelgrunden and Nysted in Denmark, Lillegrund in Sweden and Thornton Bank in Belgium.

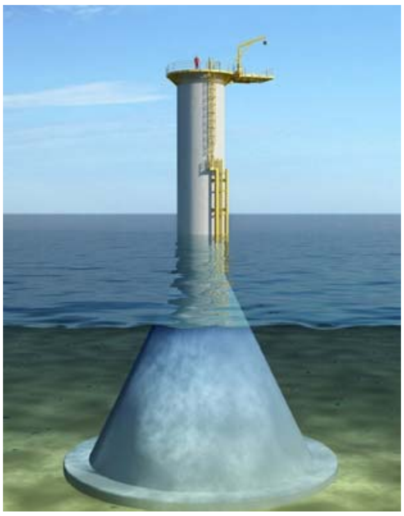

Figure 4-7: Typical GBS cone foundation (Courtesy: Ramboll)

In most cases the seabed needs to be prepared prior to installation, i.e. the top layer of material is removed and replaced by a stone/gravel bed. After the structure is placed on the seabed, the base is filled with a suitable ballast material. A steel “skirt” may be installed around the base to penetrate into the seabed and to constrain the seabed underneath the base.

The results of the preliminary gravity base design for the proposed Anholt Offshore Wind Farm are presented below:

	Smaller turbine	Larger turbine
GRAVITY BASE		
Shaft diameter	Up to 5.0 m	Up to 5.5 m
Diameter of base	Up to 20 m	Up to 25 m
Concrete weight per unit	Up to 2,000 t	Up to 3,000 t
Total concrete weight, 174/80 turbines	Up to 348,000 t	Up to 240,000 t
BALLAST		
Type	Sand or equivalent	Sand or equivalent
Volume per unit	Up to 6,000 m^3	Up to 9,000 m^3
Total volume, 174/80 turbines	Up to 1,440,000 m^3	Up to 720,000 m^3

Table 4-4: Dimensions of gravity base foundation

Ballast

The ballast is typically sand, which is likely to be obtained from an offshore source.

Seabed Preparation

The seabed will normally require preparation prior to the installation of the concrete gravity base. This is expected to be performed in the following sequence, depending on ground conditions, and available plant:

- The top surface of the seabed is removed to a level where undisturbed soil is encountered, using a back-hoe excavator aboard a barge, with the material loaded aboard split-hopper barges for disposal.
- Stone/gravel is deposited into the hole to form a firm level base.

The quantities for the seabed preparation very much depend on the ground conditions. Below is given the quantities for an average excavation depth of 2m, however large variations are foreseen, as soft ground are expected in various parts of the area:

	Smaller turbines (174 nos)	Larger turbines (80 nos)
Size of excavation (approx.)	Up to 1,300 m^2	Up to 2,000 m^2
Material excavation (per base)	Up to 2,600 m^3	Up to 4,000 m^3
Stone replaced into excavation (per base)	Up to 750 m^3	Up to 1,100 m^3
Total material excavated	Up to 452,000 m^3 (*)	Up to 320,000 m^3 (*)
Total stone replaced	Up to 130,000 m^3	Up to 90,000 m^3

Table 4-5: Estimated quantities of sea bed preparation

(*) For excavation depths of further 4 to 8m at 20% of the turbine locations, the total excavated material would increase by around 100%

The approximate time it takes for each excavation with an average depth of 2m is expected to be 3 days, with a further 3 days for placement of stone.

Disposal of Excavated Materials

The material excavated during the seabed preparation works will be loaded onto split-hopper barges for disposal. Each excavation is expected to produce 5 to 10 barge loads, hence for 174 turbines the required nos. of barges will be around 800 to 1700 and for the 8o turbines around 400 to 800.

The Client will determine the possible range of beneficial uses of the spoil material, including using the material as ballast within the structure or as scour protection material or for port construction. Should beneficial use not be feasible, the material will be disposed at sea at a registered disposal site.

Installation Sequence

The installation of the concrete gravity base will likely take place using a floating crane barge, with attendant tugs and support craft. The bases will either be floated and towed to site or transported to site on a flat-top barge. The bases will then be lowered from the barge onto the prepared stone bed and filled with ballast.

Figure 4-8: Transport to site of GBS. Rødsand (Courtesy: Aarsleff)

Figure 4-9: GBS under construction. Thornton Bank (Courtesy: Cowi)

Figure 4-10: Transport to site of GBS. Thornton Bank (Courtesy: Cowi)

Physical Discharges to Water

There is likely to be some discharge to water from the material excavation process. A conservative estimate is 5% material spill, i.e. up to between 130 and 200 m^3 for each base, over a period of 3 days per excavation.

Noise Emissions

Noise emissions during construction are considered to be very small.

4.3 Offshore Foundation Ancillary Features

The foundations will require the following ancillary features for safety and operational protection of equipment:

4.3.1 Access platform arrangements for crew access/equipment transfer

Description

The access platform comprises one or more ladders, enabling access to the foundation at any water level. In addition, a platform at the top of the ladder is necessary for crew safety. Both these features will be constructed from steel. The structures will have provisions for personnel safety, e.g. life-rings.

Installation

The access platform will be lifted into place by the jack-up barge during the main construction works.

4.3.2 Cable entry and protection features

Description

The wind turbines in the array will be inter-connected by subsea cables to provide both power and telemetry links. Provision is made for the entry and protection of the cables.

The cables are most likely to be installed in a “J-tube” arrangement, a steel tube of approximately 250mm diameter attached to the side of the turbine support structure extending from above the high water level to the seabed. Each turbine structure will have between two and four J-tubes.

Installation

For the gravity base options, the cable entry and protection provisions will be pre-installed (most likely welded) onto the support structure at the quayside. For driven piles, where there is the likelihood of the cable entry feature being vibrated off the structure by the driving procedure, the features will be subsequently secured onto the structure by bolting.

4.4 Corrosion Protection

Corrosion protection on the steel structure will be achieved by a combination of a protective paint coating and installation of sacrificial anodes on the subsea structure.

The anodes are standard products for offshore structures and are welded onto the steel structures. The number and size of anodes would be determined during detailed design. The total expected yearly emission of aluminium would be 5 to 10t, depending on the number of turbines.

4.5 Scour Protection

Scour is the term used for the localised removal of sediment from the area around the base of support structures located in moving water. If the bed is erodible and the flow is sufficient high a scour hole forms around the structure.

There are two different ways to address the scour problem. The first is to allow for scour in the design of the foundation (thereby assuming a corresponding larger water depth at the foundation) or to install scour protection around the structure such as rock dumping or fronded mattresses of polypropylen.

The decision on whether to install scour protection, in the form of rock, gravel or frond mats, will be made during a detailed design.

4.5.1 Installation

If scour protection is required the protection system normally adopted consists of rock placement. The rock would be graded and loaded onto a suitable rock-dumping vessel at a port. The rock will be deployed from the host vessel either directly onto the seabed from the barge, via a bucket grab or via a telescopic tube.

4.5.2 Monopile

Depending on the hydrodynamic environment the horizontal extent of the armour layer can be seen according to experiences from former projects in ranges between 10 and 15m having thicknesses between 1 and 1.5m. Filter layers are usually of 0.8m thickness and reach up to 2.5m further than the armour layer. Expected stones sizes range between d_{50} = 0.30m to d_{50} = 0.5m. The total diameter of the scour protection is assumed to be 5 times the pile diameter. The total volume of cover stones will be around 1,000/850 m³ per foundation, or up to 80,000/148,000 m³ for 80 nos. larger turbines /174 nos. smaller turbines.

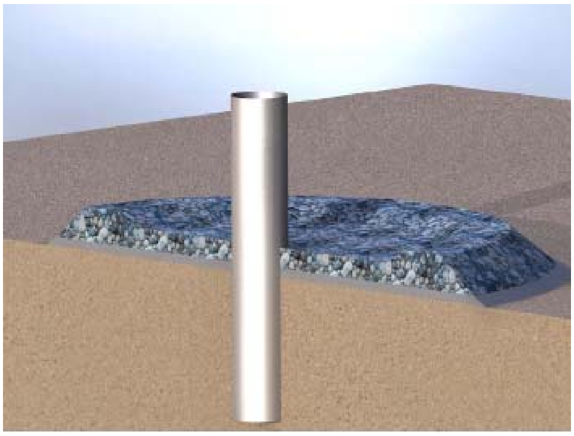

Figure 4-11: Scour Protection Monopile Foundation (Courtesy: Ramboll)

4.5.3 Gravity Base

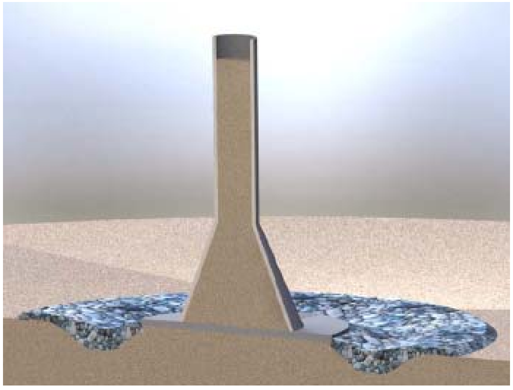

Figure 4-12: Scour Protection GBS Foundation (Courtesy: Ramboll)

Scour protection may be necessary, depending on the soil properties at the installation location. The envisaged design for scour protection may include a ring of rocks around the in-situ structure. The volume are estimated to be 800–1100 m^3 per foundation, and up to around 90,000/140,000 m^3 for 80 nos. larger turbines /174 nos. smaller turbines.

4.5.4 Alternative Scour Protection

Alternative scour protection systems may be introduced by the contractor. Such alternative could be the use of mats. The mats are attached in continuous rows with a standard frond height of 1.25m. The mats are diver-installed and no heavy lifting equipment is necessary.

4.6 Offshore Transformer Platform

Figure 4-13: Transformer Station. Rødsand (Courtesy: SEAS)

Energinet.dk will build and own the transformer platform and the high voltage cable to the shore. The cables from the wind turbines will be routed through J-tubes onto the transformer platform, where they are connected to the 33 kV switchgear located inside the transformer platform. Two or three 33 to 220 kV transformers connects the 33 kV switchgear to the 220 kV cable, which runs from the transformer platform to the shore and further on to the existing onshore transformer station Trige, where it is connected to the existing transmission network via a 220/440 kV transformer.

The transformer platform is placed on a location with a sea depth of 12-14 metres and approximately 25 km from the shore of Djursland. On the platform the equipment is placed inside a building and on top of the platform a helipad is located.

In the building there will be a cable deck, two decks for technical equipment and facilities for emergency residence. The technical equipment has the following components:

- A 33 kV switchgear, where the 33 kV cables from the wind turbines are connected. The switchgear is designed for an expansion with a bay for a 33 kV cable connecting to the island Anholt in the future.
- The 220/33/33 kV transformers with on-line tap changers are connected to the busbars in the 33 kV switchgear.
- 220 kV GIS switchgear, which connects the transformers with the 220 kV cable going to the shore.
- Two 33/0,4 kV transformers for auxiliary supply to the platform.
- One emergency diesel generator with a diesel tank.
- Batteries serving as backup for the control system.

Furthermore there will be control and scada facilities for remote and local monitoring and control of the wind turbines and the platform, first aid facilities, communication equipment, storage for spare parts, repair shop for minor maintenance.

Figure 4-14 and 4-15: Installation of transformer station. Horns Rev I. (Courtesy: ENDK)

The platform will have foot print on the seabed of up to 60 by 60 metres. The top of the platform will be up to 26 metres above sea level. The foundation for the platform will be a concrete gravitation base, a steel jacket or a monopile foundation.

As access to the platform is expected to be by boat and helicopter.

4.6.1 Lighting and Marking

There is no common practice for safety zones at Danish offshore wind farms since the need for protection varies. At Nysted, ‘restriction in practices’-zones have been applied for the entire park for trawling, aggregate extraction and dredging or anchoring (for non-project vessels).

Safety zones may be applied for Anholt Offshore Wind Farm area or parts hereof. For the offshore transformer platform a prohibited entry zone of minimum 50m radius is foreseen for non-project vessels.

In the event that a permanent safety zone will be established around the transformer platform it will be marked with yellow lanterns, as also used on the turbines, when the platform is placed within the wind farm entity. In case that the transformer platform is placed isolated from the wind farm it should be marked with white lanterns. The lanterns will have flashing lights and an effective reach of at least 5 nautical miles compared to the recommendations by IALA (International Association of Lighthouse Authorities). The safety zone will also be marked with appropriate buoys.

The establishment of safety zones at Anholt Offshore Wind Farm are subject to application to Søfartsstyrelsen. The exact specifications of the marking of the safety zones will be determined by Farvandsvæsenet.

4.7 Subsea Cabling

4.7.1 Inter-Array Cables

33 kV cables. The wind turbines will be connected by 33 kV submarine cables, which will be embedded not less than 1 meter into the sea bottom. The 33 kV cables will connect the wind turbines in groups to the transformer platform. The 33 kV sea cables will be PEX insulated or similar with armouring. There will be up to 20 cable connections from the platform to the wind turbines and possible one cable connection to Anholt.

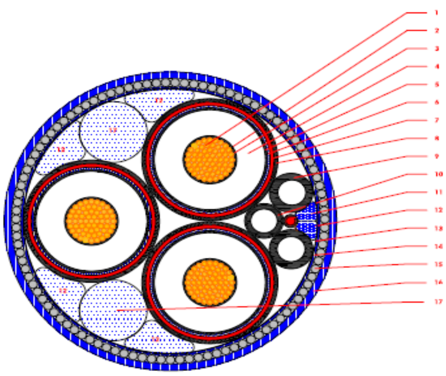

Figure 4-16: Typical data of export cable

No	Constituens
1	Compacted copper strands
2	Semiconducting filling compound
3	Conductor screen, semiconducting XLPE
4	Insulation, XLPE
5	Insulation screen, semiconducting XLPE
6	Water swellable tape
7	Lead Sheath, alloy 1/2c
8	Sheath, semiconducting PE
9	Filler element, PP pipe
10	Filler element, PP pipe w/semicond. layer
11	Fibre optical cable
12	Filler element, PP cordell
13	Textile tape
14	Armour beding, PP-yarn and bitumen
15	Armour, galvanizes steel wires
16	Outer serving, PP-yarn and bitumen
17	Filler element, PP rope

4.7.2 Export Cables

220 kV cable. From the transformer platform a 220 kV cable is laid towards west to the shore at Saltbæk north of Grenå. The distance to shore is 25 km. The sea cable will be a PEX insulated three phase cable with single armouring. The cable will be embedded more than 1 metre into the sea bottom.

4.7.3 Subsea Cable Installation

The installation of the inter-array cables is likely to be carried out by a specialist cable laying vessel, with the cables stored either on reels or a carousel designed to carry the necessary lengths and maintain the minimum bend radius.

The vessel is likely to be fully equipped with specialised cable laying equipment, including cable tensioners and a full survey suite to provide details of the final cable positions. The vessel will follow the cable route either through use of a four or eight point moving system or an either fully DP (Dynamically Positioned) or a DP assisted operation.

Figure 4-17: Cable Ship

All the subsea cables will be buried in order to provide protection from fishing activity, dragging of anchors etc. A burial depth of approximately 1m or more is expected. The final depth of burial will be determined at a later date and will vary depending on more detailed soil condition surveys and the equipment selected.

The cables are likely to be buried using a combination of two techniques; either using:

- an underwater cable plough that executes a simultaneous lay and burial technique. Such an operation mobilises very little sediment;
- cable burial ROV (Remote Operated Vehicle) that utilise high-pressure water jets to fluidise a narrow trench into which the cable is located. The jetted sediments will settle back into the trench.

Figure 4-18: Plough
(Courtesy: CTC Marine)

Figure 4-19: Jet Trenching ROV
(Courtesy: CTC Marine)

4.8 Lighting and Marking

There is no common practice for safety zones at Danish offshore wind farms since the need for protection varies. At Nysted, ‘restriction in practices’-zones have been applied for the entire park for trawling, aggregate extraction and dredging or anchoring (for non-project vessels).

Safety zones may be applied for Anholt Offshore Wind Farm area or parts hereof. A 200m safety zone on each side of all cables is expected.

In the event that a permanent safety zone will be established around the cables arrays the zone will be marked with appropriate buoys.

The establishment of safety zones at Anholt Offshore Wind Farm are subject to application to Søfartsstyrelsen. The exact specifications of the marking of the safety zones will be determined by Farvandsvæsnet.

4.9 Wind Farm Layout

The wind farm layout is not yet decided, but will be established at a later stage. Indicative illustrative layouts are given below for 2.3MW and for 5.0MW turbines.

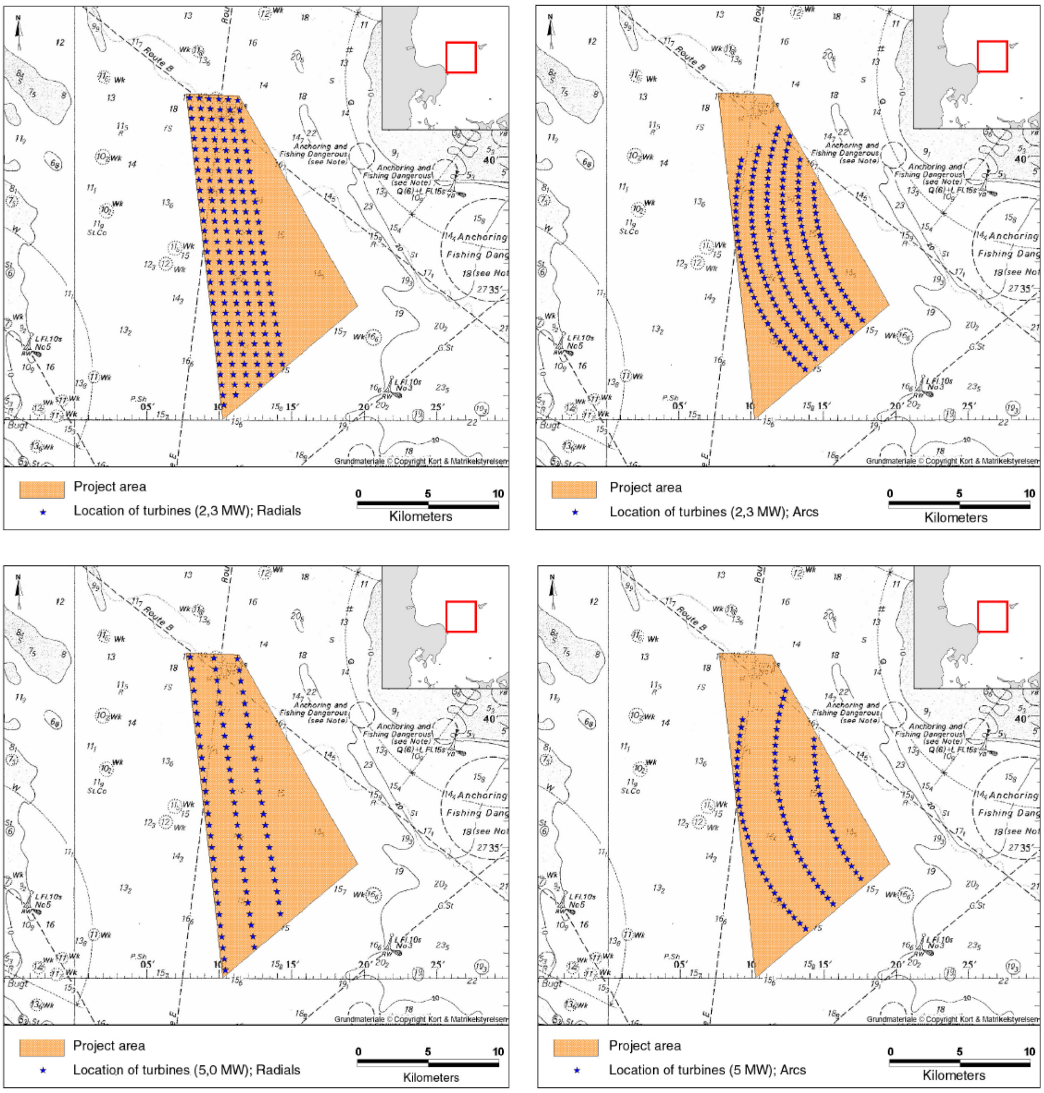

Figure 4-20: Indicative layouts

5. Offshore Construction

5.1 Access to Site and Safety Zones

The construction of the proposed Anholt Offshore Wind Farm project is scheduled to take place all through the year. Construction activity is expected for 24 hours per day until construction is complete.

A safety zone of 500m will be established to protect the project plant and personnel, and the safety of third parties during the construction and commissioning phases of the wind farm.

The extent of the safety zone at any one time will be dependent on the locations of construction activity. However the safety zone may include the entire construction area or a rolling safety zone may be selected.

It is intended that third parties will be excluded from any safety zone during the construction period. The temporary markings will include yellow light buoys with an effective reach of at least 2 nautical miles. All buoys will further be equipped with yellow cross sign, radar reflector and reflector strips. Regular Notice to Mariners will be issued minimum 6 weeks before laying out of markings or construction works begins and as construction progresses.

The same will apply for laying of the export cables.

The establishment of temporary safety zones at Anholt Offshore Wind Farm are subject to application to Søfartsstyrelsen. The exact specifications of the marking of the safety zones will be determined by Farvandsvæsnet.

5.2 Construction Vessels

The types of construction vessel which will construct the wind farm will be selected by the nominated contractor, however the main types of vessels for each tasks are presented below:

Task	Likely Type of Construction Vessel
Pile Installation	Jack-up barge
Gravity Base Installation	Floating barge
Wind Turbines	Jack-up barge
Scour Protection	Construction barge or dedicated barge
Cable Installation	Dedicated cable laying vessel
Offshore Transformer Station	Floating barge
Crew Transfer	Workboat

Table 5-1: Typical construction vessels

To optimise the construction programme, it is likely that installation of wind turbines, foundations and cables will be undertaken on the site at the same time, although not necessarily in the same part of the site. Therefore it is likely that at least 20-30 vessels (including support crafts) may be on site at any one time.

5.3 Lighting and Marking

The construction area will be disseminated through the Notice to Mariners procedure. The construction area and incomplete structures will be lit and marked in accordance with the protocol recommended by Favandsvæsenet and Statens Luftfartsvæsen.

5.4 Construction Programme

An indicative construction programme is presented below, and is based upon two construction seasons.

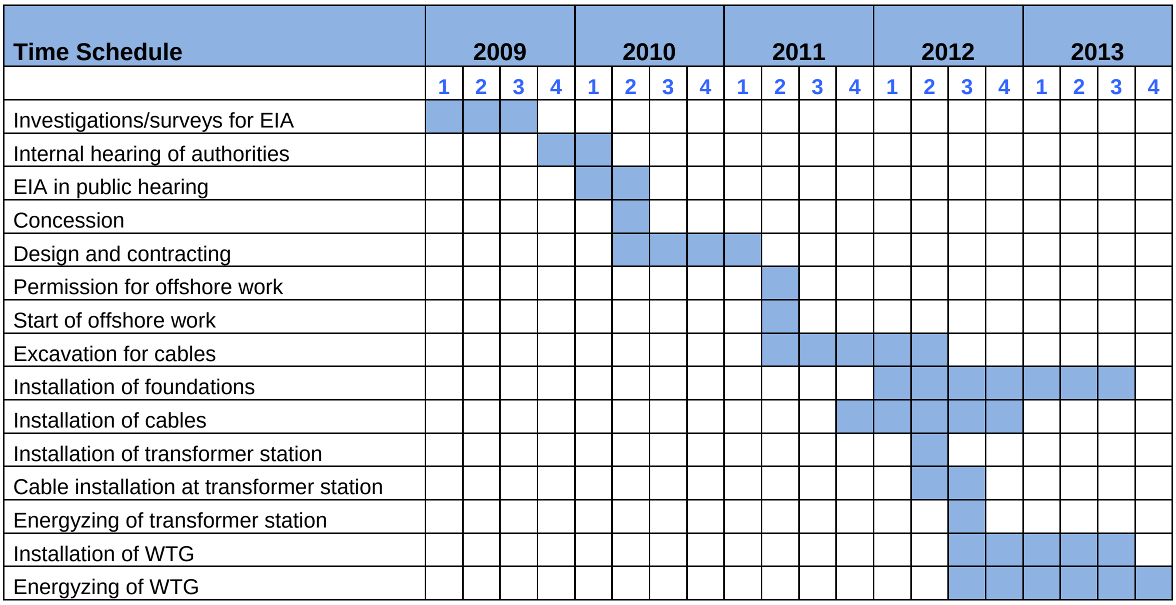

Figure 5-1: Indicative construction programme

5.5 Construction Management (Environmental)

During construction (and decommissioning) some discharges to atmosphere will arise from the marine vessels required to undertake these stages of the development. In addition, there is a small risk of accidental discharges from the turbine array or marine vessels associated with construction and decommissioning. These are considered to be minimal.

There are no anticipated solid discharges into the marine environment during the construction phase.

A comprehensive Environmental Management System is expected to be implemented prior to construction in consultation with statutory authorities, with a suite of complementary management plans corresponding to different aspects of the construction activity. The Environmental Management System would form a component part of the construction contract for the development.

6. Onshore Components

6.1 Cable Landfall

At sea the submarine cable is laid from a vessel with a large turn table. Close to the coast, where the depth is inadequate for the vessel, floaters are mounted onto the cable and the cable end is pulled onto the shore. The submarine cable is connected to the land cable close to the coast line via a cable joint. Afterwards the cables and the cable joint are buried into the soil and the surface is re-established.

6.2 Onshore Cabling

On shore the land cable connection runs from the coast to compensation substation 2-3 km from the coast and further on to the transformer station Trige near Århus. The land-cable consist of 3 single-phase 220 kV PEX insulated cables, located in a common cable trench. The cables come in lengths of approx. 1 km, and they are interconnected by cable joints. After the installation of the cables the trench will be filled with excavated soil and the surface will be re-established. Inside the compensation station the cable is connected to a compensation coil, which compensates the reactive current generated by the cable. The compensation coil and the associated 220 kV switchgear will be located in a building.

6.3 Sub-Station Works

At the transformer station Trige a new 220/400 kV transformer, compensation coils and associated switchgear will be installed. The transformer will connect the land-cable with the existing 400 kV network inside the switchyard via a new 400 kV bay. The switchyard has sufficient space for the new equipment and need therefore not to be expanded.

7. Wind Farm Operations and Maintenance

Operation and maintenance of the offshore wind farm will continue 24 hours per day, 365 days per year, and therefore the Contractor will require access to site at any time.

7.1 Access to Site and Safety Zones

There is no common practice for safety zones at Danish offshore wind farms since the need for protection varies. At Nysted, ‘restriction in practices’-zones have been applied for the entire park for trawling, aggregate extraction and dredging or anchoring (for non-project vessels).

Safety zones may be applied for Anholt Offshore Wind Farm area or parts hereof. A 200m safety zone on each side of all cables is expected. For all turbines and for the offshore transformer station a prohibited entry zone of minimum 50m radius is foreseen for non-project vessels.

The establishment of safety zones at Anholt Offshore Wind Farm are subject to application to Søfartsstyrelsen. The exact specifications of the marking of the safety zones will be determined by Farvandsvæsnet.

7.2 Wind Farm Control

The wind turbines are configured so that they operate with a minimum of supervisory input. The turbines are monitored and controlled by micro-processors installed within the turbine tower. Should a turbine develop a fault, the status of the fault is diagnosed, and if necessary the turbine is automatically shut down for safety purposes. The turbine operation is based upon a “fail-safe” philosophy.

All information relating to on-site conditions (wind speed, direction, wave height, etc), turbine status and generated output is held within a central Supervisory Control And Data Acquisition (SCADA) system linked to each individual turbine micro-processor. The SCADA system is controlled from an operations base ashore, and allows for the remote control and shutting down of any individual turbine (or a number of turbines) should circumstances dictate.

7.3 Wind Farm Inspection and Maintenance

The wind farm will be serviced and maintained throughout the life of the wind farm from a local port, possibly located on Djursland close to the site. Following the commissioning period of the wind farm, it is expected that the servicing interval for the turbines will be 6 months.

Maintenance of the wind farm is normally separated into three different categories:

- Periodic overhauls
- Scheduled maintenance

- Un-scheduled maintenance

7.3.1 Periodic Overhauls

Periodic overhauls will be carried out in accordance with the turbine manufacturer's warranty. These overhaul campaigns will be planned for execution in the periods of the year with the best access conditions, preferably in summer.

The periodic overhauls will be carried out according to the supplier's specifications. The work scope typically includes function and safety tests, visual inspections, analysis of oil samples, change of filters, lubrication, check of bolts, replacement of brake pads, oil change on gear box or hydraulic systems.

7.3.2 Scheduled Maintenance

Scheduled maintenance applies primarily to inspections and work on wear parts susceptible to failure or deterioration in between the periodic overhauls. A scheduled inspection of each turbine is likely to take place every six months. The tasks will typically be inspection on faults and minor fault rectification.

Scheduled maintenance will be performed using small personnel craft operated from the local harbour.

7.3.3 Unscheduled Maintenance

Unscheduled maintenance applies to any sudden defects. The scope of such maintenance would range from small defects to complete failure or breakdown of main components. Such maintenance would require the intervention of construction vessels similar to those involved in the construction of the wind farm.

Inspections of support structures and subsea cables will be performed on a regular basis as will ad-hoc visits for surveillance purposes.

7.4 Consumptions and Materials

During the operation and maintenance it may be required to replace some of the components of the turbine. The list below gives a estimate of the amount of various consumptions and for a typical turbine.

There are no anticipated direct discharges to the atmosphere nor anticipated solid discharges into the marine environment during normal operation of the turbine array. All waste generated during operation, for example associated with maintenance, will be collected and disposed of by licensed waste management contractors to licensed waste management facilities onshore.

Yaw gear oil	Quantity, Litre	50-100
	Origin	Semi synthetic
	Change frequency, months	60-240
Gear oil	Quantity, litres (system)	500-700
	Origin	Semi Synthetic
	Change frequency, months	Approx. 60
Gear oil filter	Number	3
	Change frequency, months	12
Brake lining	Number of systems	1-2
	Origin (species)	Sinter metal
	Consumption per year, set	1-2
Hydraulic oil	Number of systems	2-3
	Origin (species)	Synthetic or mineral
Filters on the hydraulic oil system	Number	1-3
	Exchange frequency, months between exchange	12-60
Coolants – water	Quantity, litres	Approx. 100
	Composition	50% glucol
	Change frequency, months	36-60
Coolants – silicone oil[1]	Quantity, litre	1800
Lubricant (Main bearing)	Origin	Oil or grease
	Quantity, litres/year	6-10
Lubricant (yaw bearing)	Origin	Grease
	Quantity, litres/year	Approx. 3
Lubricant (wing bearings)	Origin	Grease
	Quantity, litres/year	6-9
Lubricant (generator bearings)	Origin	Grease
	Quantity, litres/year	1-4
Slip rings	Number	12
	Composition (% percentage metals – Origin)	80% Cu
	Consumption, kilos/year	Approx. 2-4

[1] Possible coolant-silicone oil consumption dependant on turbine type.

Table 7-1 Expected consumptions and materials.

8. Wind Farm Decommissioning

The following sections provide a description of the current intentions with respect to decommissioning, with the intention to review the statements over time as industry practices and regulatory controls evolve.

8.1 Extent of Decommissioning

The objectives of the decommissioning process are to minimize both the short and long term effects on the environment whilst making the sea safe for others to navigate. Based on current available technology, it is anticipated that the following level of decommissioning on the wind farm will be performed:

- Wind turbines – to be removed completely.
- Structures and substructures – to be removed to the natural seabed level.
- Infield cables – to be either removed (in the event they have have become unburied) or to be left safely in-situ, buried to below the natural seabed level or protected by rock-dump.
- Export cables – to be left safely in-situ, buried to below the natural seabed level or protected by rock-dump.
- Cable shore landing – to be either safely removed or left in-situ, with particular respect to the natural sediment movement along the shore.
- Scour protection – to be left in-situ.

8.2 Decommissioning of Wind Turbines

The wind turbines would be dismantled using similar craft and methods as deployed during the construction phase. However the operations would be carried out in reverse order.

8.3 Decommissioning of Offshore Transformer Platform

The decommissioning of the offshore transformer platform is anticipated in the following sequence:

- Disconnection of the wind turbines and associated hardware.
- Removal of all fluids, substances on the platform, including oils, lubricants and gasses.
- Removal of the transformer station from the foundation using a single lift and featuring a similar vessel to that used for construction.

The foundation would be decommissioned according to the agreed method for that option.

8.4 Decommissioning of Buried Cables

Should cables be required to be decommissioned, the cable recovery process would essentially be the reverse of a cable laying operation, with the cable handling equipment working in reverse gear and the cable either being coiled into tanks on the vessel or guillotined into sections approximately 1.5m long immediately as it is recovered. These short sections of cable would be then stored in skips or open containers on board the vessel for later disposal through appropriate routes for material reuse, recycle or disposal.

8.5 Disposal / Re-Use of Components

It is likely that legislation and custom will dictate the practices adopted for the decommissioning of the proposed Anholt Offshore Wind Farm. The decommissioned materials could have the following disposal methods:

- All steel components sold for scrap to be recycled.
- The turbine blades (fibre-glass) to be disposed of in accordance with the relevant regulations in force at the time of decommissioning. One potential disposal method identified is to break down the fibre-glass into a pulp for use as cavity insulation in buildings.
- All heavy metals and toxic components (likely to be small in total) disposed of in accordance with relevant regulations.

8.6 Access to Site

It is envisaged that the requirements for access to site during the decommissioning phase will be similar to those required during the construction phase.

8.7 Decommissioning Programme

A decommissioning program will be established by the nominated contractor as part of the concession.

8.8 Ongoing Monitoring

The scope and duration of the monitoring requirements post decommissioning will be agreed between the operator of the wind farm and the owner in consultation with other Government Departments and details will be included in the decommissioning programme. The operator will implement the arrangements for monitoring, maintenance and management of the decommissioned site and any remains of installations or cables that have been left in-situ in accordance with the agreement.

9. References

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