NIRAS

Offshore and Onshore Technical Project Description

Aflandshage Windfarm

WAHA01-GEN-PRO-05-000014 HOFOR WIND A/S

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Introduction

This document outlines the proposed technical aspects of the onshore and offshore development of Aflandshage Wind Farm, and has been written in close collaboration between HOFOR Vind A/S and NIRAS. HOFOR Vind A/S has included technical input from COWI, Rambøll and New Power Partners in the document.

Part 1 includes the offshore aspects including wind turbine generators (WTG) and foundations, sub-sea internal array, export cables.

Part 2 includes the landfall, and Part 3 the onshore aspects including export cables and substation.

Due to a possible international tendering process for the construction of the offshore wind farm part 1 is in English, whereas parts 2 and 3 are in Danish.

This Technical Project Description includes overall three alternative solutions based on a small size turbine, an intermediate size turbine, and a large size turbine. These three alternative solutions form the basis for the EIA assessment that will lead to the license to construct Aflandshage Wind Farm.

Each technical component will be addressed, with respect to construction, installation, operation and maintenance, and decommissioning. Aflandshage Wind Farm is expected to be in operation in up to 35 years with a license for 30 years of operation with a possible extension of 5 years operation.

It should be noted that a more detailed specific design most likely will be made prior to the initialization of the construction phase. In order to make this design, detailed investigations will be conducted as described in section 7.1.

HOFOR has worked in parallel with the development of two wind farms, Nordre Flint and Aflandshage, for several years. HOFOR received license for pre-investigations for both wind farms on March 6, 2019, and submitted Environmental Impact Assessment (EIA) reports for both wind farms on December 21, 2020.

This EIA material concerns Aflandshage Wind Farm. The EIA material for Aflandshage is now sent for public consultation (from November 2021 to January 2022), while dialogue with authorities about EIA material for Nordre Flint is still ongoing. The EIA material for Nordre Flint is expected to be sent for public consultation in 2022.

PART 1: OFFSHORE / ANLÆG PÅ HAVET

1 Offshore project - location and layout

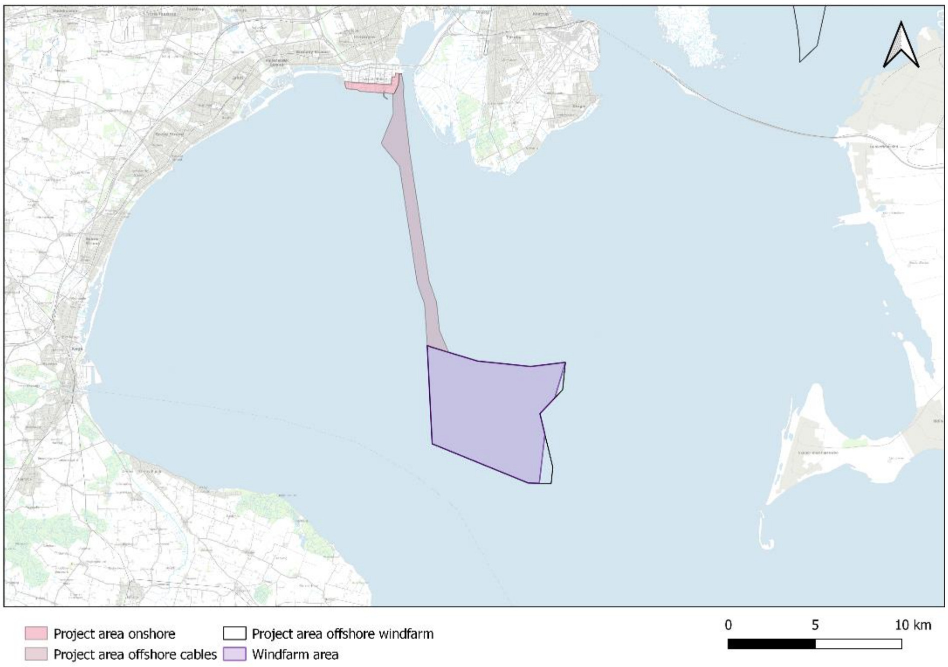
Aflandshage Wind Farm is located south of Amager in Øresund within a 56,5 km^2 project area (Figure 1.1). The offshore project area is a combination of a 42 km^2 offshore windfarm area reserved for turbines and inter-array cables as well as a possible offshore substation for transforming the power generated by the turbines, before it is transported onshore. The offshore substation can also be associated with one or more turbine foundations. The project area also consists of a 12,5 km^2 cable corridor reserved for installation of up to 6 parallel grid connection cables transporting the electrical power to Energinet's 132 kV substation onshore at Avedøreværket, which is further detailed in part 3, section 3.

1.1 Turbine layouts

The offshore wind farm is expected to have an installed effect of up to 300 MW.

The offshore wind farm will be installed with either a small turbine of 5.5 – 6.5 MW, an intermediate turbine of 7.5 – 8.5 MW, or a large turbine of 9.5 – 11.0 MW. The maximum number of turbines will therefore be 45 turbines with a small turbine size (5.5 MW), 31 turbines with an intermediate turbine size (8 MW) or 26 turbines with a large turbine size (11.0 MW). The layout of the offshore wind farm is optimized in relation to the prevalent wind direction from south-west to maximize the total production during the lifetime of the offshore wind farm. The layout is defined in a harmonic pattern to minimize the visual impact of the offshore wind farm. The maximum height of turbines will be defined by the 11.0 MW turbine at 220 m.

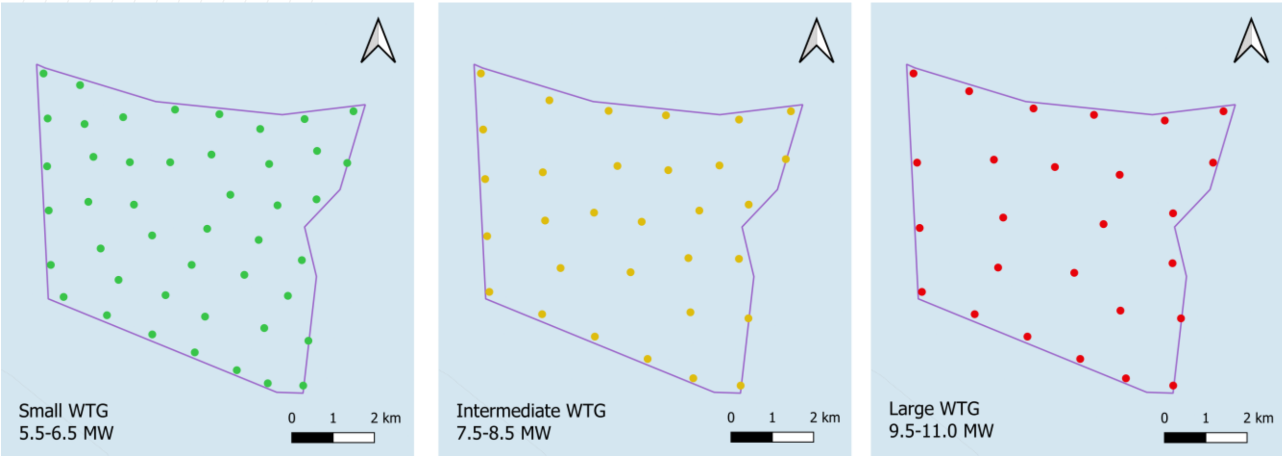
Figure 1.1: Project area onshore and offshore. ©SDFE



The layout for the offshore wind farm has been developed by HOFOR. Layouts are presented for the small WTG (**W**ind **T**urbine **G**enerator) at 5.5-6.5 MW, intermediate WTG at 7.5-8.5 MW, and large WTG at 9.5-11.0 MW turbine sizes for the purpose of **E**nvironmental **I**mpact **A**ssessment (EIA). Based on an optimisation of several parameters the final layout subject to the construction permit might include minor changes to the layout but within the frame of the Environmental Impact Assessment.

Location and layouts are shown in Figure 1.2. Details including coordinates for the individual wind turbine positions in the presented layouts can be found in the layout report and in Appendix 1.

Figure 1.2: Location of WTG's. The possible layouts for Aflandshage Wind Farm for small WTG (5.5-6.5 MW), intermediate WTG (7.5-8.5 MW), and large WTG (9.5-11 MW) are shown respectively.



1.2 Offshore cables

The cables for grid connection of the offshore wind farm will be installed in a cable corridor and will be connecting to Energinet's onshore substation on Avedøreværket, which has been defined by Energinet as the connection point for Aflandshage Wind Farm. The offshore cable corridor for grid connection covers an area of approximately 12.5 km^2. The onshore project is described in detail in part 3, section 3.

The offshore grid connection cable system will consist of up to 6 parallel cables if 33 or 66 kV cables are installed, or only one 132 kV cable if the substation is located offshore. Each export cable will be installed in an approximately 16 km cable corridor connecting the offshore wind farm to land.

Each wind turbine will be connected in an internal grid of inter-array cables consisting of up to total length of approximately 40 km cables for the large turbines and 50–56 km of inter-array cables for the small turbines dependent on whether power transformation is taking place onshore or offshore.

1.3 Offshore substation layouts

The wind turbines produce power at either 33 kV or 66 kV. This can be transformed to 132 kV by installing a single offshore substation placed on a platform with its own foundation structure, or at a substation placed onshore (See Part 3 Onshore, chapter 3 Stationsanlæg").

1.3.1 Offshore substation platform

A possible offshore **H**igh **V**oltage **A**lternating **C**urrent (HVAC) substation can be installed centrally in the windfarm relatively close to the cable corridor for the export cable as shown in Figure 4.1.

The offshore substation platform is expected to have a length of 35–40 m, a width of 25-30 m and a height of 15-20 m. The highest point of a platform is expected to be 30–35 m above sea level.

The array cables from the wind turbines will be routed through J-tubes onto the HVAC platform, where they are connected to a Medium Voltage (MV) switch gear (33 kV or 66 kV), which also is connected to High Voltage (HV) transformers.

The platform is designed with containers collecting oil or diesel in case of leakages. The capacity is equivalent to or larger than the largest amount of oil or diesel contained at the platform.

The platform will be without any light, when no people are onboard except from required navigational lanterns which will be flashing synchronously with the wind turbines, having an effective reach of at least 5 nautical miles corresponding to an intensity of approximately 75 candelas.

The platform will be provided with boat landing to make transport by boat possible.

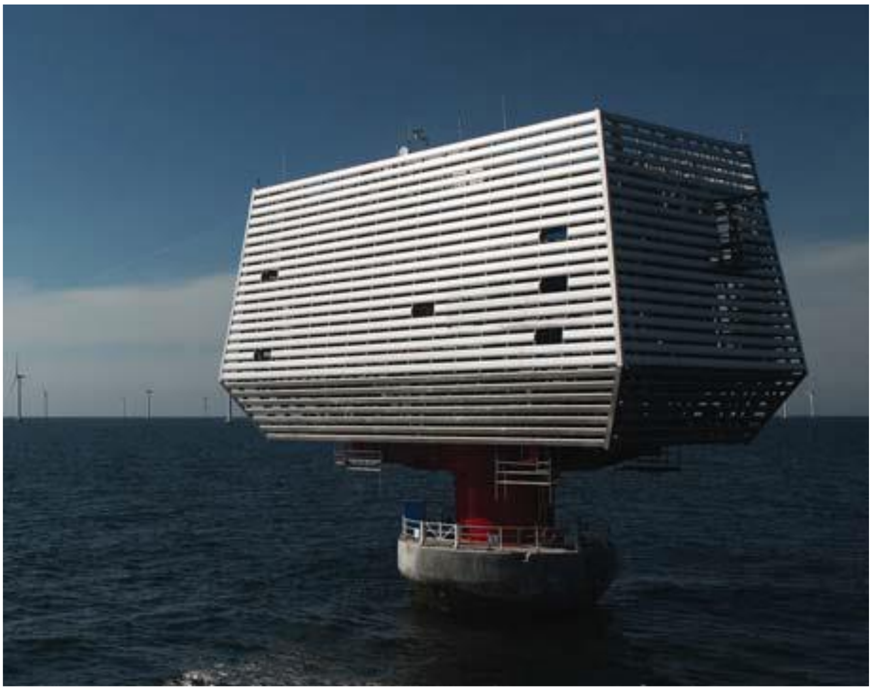


Figure 1.3: Example of an offshore substation with transformer at Rødsand II Havmøllepark operated by Energinet (Image by EON, now RWE Renewables).

1.4 Flight zones

The obstacle limitation area associated with Copenhagen Airport (CPH) is shown in Figure 1.4 together with the minimum distance to air traffic facilities for wind turbines at 15 km.

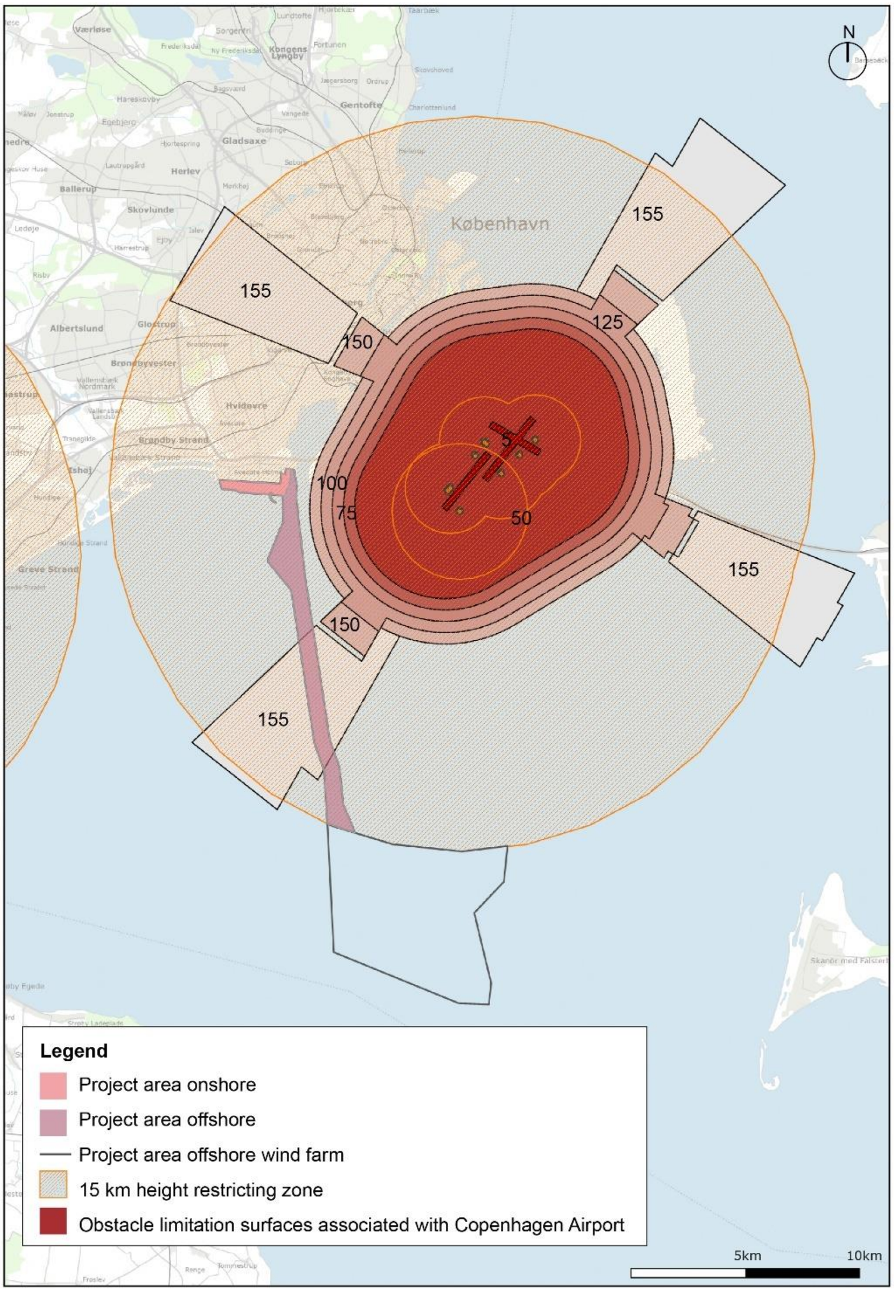


Figure 1.4: Overview of obstacle limitation surfaces associated with Copenhagen Airport and project area for inter-array cables and the windfarm. Numbers given in subareas indicate maximum acceptable height of possible obstacles in meters. ©SDFE

Around CPH there are guiding restrictions to height of buildings and other structures in different obstacle limitations areas in connection to the CPH runway layout and radar positions. In the take off and approach airspaces there is a height restriction of 25 m, in the horizontal zone there is a height restriction of maximum 50 m, and in the conical zone there is a restriction increasing from 50 m in the inner zone up till 155 m in the outer zone.

According to guidelines, turbines should not exceed a total height of more than 100 m within a 15 km zone to CPH. The planned Aflandshage Wind Farm lies outside of this zone.

2 Wind turbines

In the following section the technical description of Wind Turbine Generators (WTG) is presented.

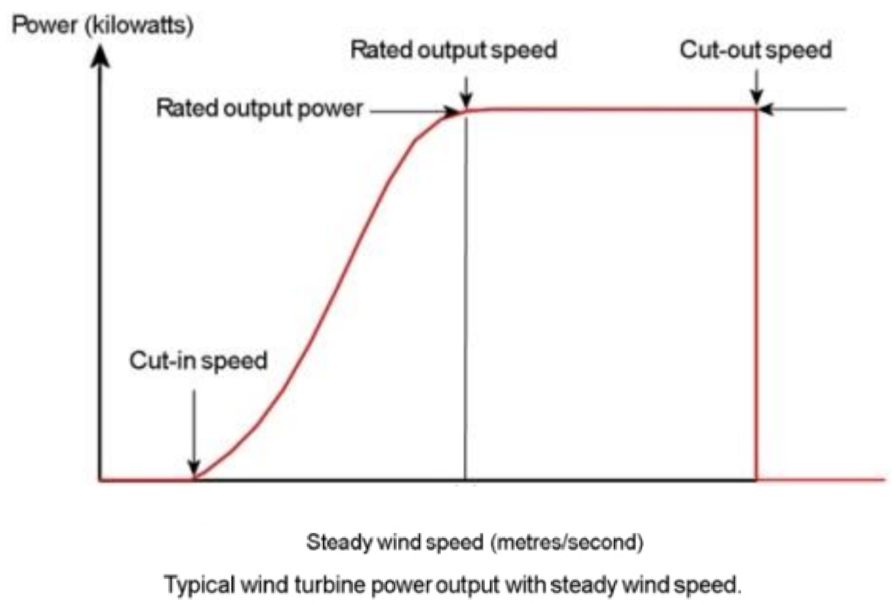
2.1 Description

The exact design of the wind turbine will depend on the chosen manufacturers. All known available offshore WTG types comprise a tubular tower and three rotor blades attached to a nacelle housing the generator, gearbox (where relevant) and other equipment. Blades will turn clockwise, when viewed from the windward direction.

The WTGs will be generating power when the wind speed at hub height is between the cut-in wind speed, typically 3 to 5 m/s and the cut-out wind speed, typically the power output will decrease between 28 to 35 m/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 14 m/s at hub height depending on the IEC class of the wind turbine. The design of the turbines ensures safe operation, and the turbines shut down automatically, if the wind speed exceeds the designed max cut-out wind speed. Once the wind speed is below this threshold, which could be 25 m/s, production is resumed. The WTGs will not be generating power in approximately 6 % of the time due maintenance or because of too low or too high wind speeds.

The typical power curve, and cut-in, cut-out and rated output wind speeds are shown below in Figure 2.1.

Figure 2.1: Typical WTG power curve[1]



[1] Energinet April 2015, Technical Project Description for Offhore Wind Farms (200 MW). Offshore Wind Farm at Vesterhav Nord, Vesterhav Syd, Sæby, Sejerø Bugt, Smålandsfarvandet and Bornholm

2.2 Dimensions

The dimensions of the turbines will not exceed a maximum tip height of 220m above mean sea level for the largest turbine size (11.0 MW).

Assumptions on WTG dimensions for the three alternative WTG types are presented in Table 2.1. The assumptions are based on information on currently available WTGs on the market and announced WTGs.

Table 2.1: WTG maximum dimensions used in the EIA. In brackets the general range of dimensions used by HOFOR Wind A/S in the project development is shown.

Turbine capacity (MW)	Rotor diameter (m)	Total height DVR90 (m)	Hub height DVR90 (m)	Height over HAT (m)
Small WTG 6.5 (5.5-6.5)	176 (160±10%)	210 (191±10%)	122 (111±12%)	34 (20-52)
Intermediate WTG 8.5 (7.5-8.5)	184 (167±10%)	212 (193±10%)	120 (109.5±12%)	28 (20-32)
Large WTG 11.0 (9.5-11.0)	200 (187±10%)	220 (210.5±10%)	120 (118.75±12%)	20 (20-46)

The air gap between Mean Sea Level (MSL) and the lower wing tip will be determined based on the actual project. However, it is expected that the Danish Maritime Authority (DMA) will request a minimum of approximately 20 metres between the **H**ighest **A**stronomical **T**ide (HAT) and the lower wing tip. The determining factors for acceptable air gap will be:

- Regulatory requirements
- Sufficient air gap between the access platform on the turbine foundation and the blade tip. (Typically, the elevation of the platform is determined by the extreme wave height)

In Table 2.1 the maximum dimension of the wind turbine parameters are given for each alternative of turbine size. In brackets the general range of turbine dimensions that HOFOR Wind A/S are using in the project development is given. These ranges of dimensions establish the maximum and minimum figure for rotor diameter, Total height, Hub height and HAT free space unless the dimension are determined by the pre-investigation requirement of maximum total height of 220 m above DVR90 or the HAT free space set at 20 m. Further the maximum and minimum dimensions of each parameter must follow the interdependencies given by the mathematical formulas for calculation of Hub Height and HAT free space below:

Hub height = Total height - ½ x rotor diameter
HAT free space = Hub height - ½ x rotor diameter

In the formulas above the total height and the rotor diameters are the guiding figures. In the tenders that HOFOR Wind A/S will hold before construction the ranges for turbine dimensions given in Table 2.1 and in respect of the legal maximum total height of 220 m and a minimum HAT free space of 20 m will be included.

For the EIA assessment the ranges of dimensions given in Table 2.1 are given as four types of combined fixed dimensions that are related to each other in terms of rotor diameter, total height, hub height and HAT free space.

The following combinations of wind turbine dimensions (turbine type) will be included:

Type 1: Largest dimensions of total height and rotor diameter
Type 2: Smallest dimensions of total height and rotor diameter
Type 3: Mean dimension of rotor diameter and total height
Type 4: Smallest rotor diameter and largest total height

These combinations will lead to the turbine dimensions given in Table 2.2.

Table 2.2: Example of 4 different turbine types for small turbine, intermediate turbine and large turbine with combinations of dimensions (meters) given in Table 2.1.

Parameter	Type 1	Type 2	Type 3	Type 4
Small WTG, 5.5 – 6.5 MW				
Rotor diameter	176	144	160	144
Total height	210	172	191	210
Hub height	122	100	111	138
HAT free space	34	28	31	66
Intermediate WTG, 7.5 – 8.5 MW				
Rotor diameter	184	150	167	150
Total height	212	174	193	212
Hub height	120	99	110	137
HAT free space	28	24	26	62
Large WTG, 9.5 – 11.0 MW				
Rotor diameter	200	168	187	168
Total height	220	190	211	220
Hub height	120	106	117	136
HAT free space	20	22	24	52

Ahead of construction, the DMA will need to approve the detailed design of the offshore wind farm for factors relevant for safety of navigation.

2.3 Materials

In Table 2.3 below, the raw materials including their quantities, are specified for the small (5.5 – 6.5 MW), intermediate (7.5-8.5 MW), and large (9.5 - 11.0 MW) turbines.

Table 2.3: Materials estimate for a small, intermediate and a large turbine. All quantities shown depend on the exact wind turbine model chosen.

Part	Materiel type	Turbine capacity	Quantity (t)
Nacelle	Steel/Glass reinforced plastic (GRP)	5.5-6.5 MW	260
		7.5-8.5 MW	320
		9.5-11.0 MW	440
Hub	Cast iron	5.5-6.5 MW	50
		7.5-8.5 MW	70
		9.5-11.0 MW	80
Blades	GRP	5.5-6.5 MW	30 per blade
		7.5-8.5 MW	34 – 40 per blade
		9.5-11.0 MW	35 – 46 per blade
Tower	Steel	5.5-6.5 MW	350 (dependent on hub height - interface level)
		7.5-8.5 MW	520 (dependent on hub height - interface level)
		9.5-11.0 MW	600 - 750 (dependent on hub height - interface level)

2.4 Oils and fluids

Wind turbines typically contain lubricants, hydraulic oils and cooling liquids. Typical quantities are shown in Table 2.4 below. No fluids are expected to be released to the surroundings during installation, operation, maintenance or decommissioning. The wind turbine is equipped to collect potential lubricant spills from turbine components.

Table 2.4: Fluids and lubricants.

Fluid	Approximate Quantity, litres		
	Small WTG 5.5-6.5 MW	Intermediate WTG 7.5-8.5 MW	Large WTG 9.5-11.0 MW
Gear Oil (synthetic oil)	800	1,600	1,900
Hydraulic oil (synthetic oil)	<300	1,000	1,200
Yaw gears (gear oil)	< 80	160	100
Transformer Oil (silicone-based fluid)	< 1,450	5,000	6,000

2.5 Colour

The typical colour of the turbine towers and blades are light grey (RAL 7035 or similar). Transition pieces may be used in the connection between the foundation and the turbine. The Danish Maritime Authority (DMA) requires, with reference to the international standards[2], a yellow marking of the wind turbine tower from water level, High Astronautical Tide (HAT) up to a height of 15 meters above HAT.

For monopile foundations above sea level, it is expected that the foundation will be painted yellow apart from a possible concrete ice conus and the platform which will be greyish concrete coloured.

If the gravity base structure foundation type is chosen, the visible structures between the water surface and the tower bottom will be grey as the natural colour of the concrete. The exact requirement will be defined by the Danish Maritime Authority (DMA) based on the specific project and international guidelines etc.

The turbines will be marked with identification numbers. The numbers will be approximately 1 m high. The ID number plates are typically placed on the railing of the access platform, depending on the requirements of height in the EIA permit.

2.6 Lighting and marking

The wind turbines must be equipped with markings visible for vessels and aircrafts in accordance with requirements by the DMA and the Danish Transport Authority (DTA), respectively.

The light markings for aviation as well as for shipping and navigation will most likely be required to work synchronously.

The anticipated requirements for lights and markings are described below. However, the actual requirements in relation to lighting will be determined by the DMA and the DTA when the layout of the offshore wind farm and height of the wind turbines have been finally decided.

2.6.1 Marking for navigation

The light markings on the turbines in relation to shipping and navigation is expected to comply with the following description but must be approved by the DMA, when the final wind farm layout has been decided, and in due time before construction. The markings described below are standard descriptions where deviations and special conditions can be requested from the DMA.

- All turbines placed in the corners and at sharp bends along the peripheral (significant peripheral structures = SPS) of the offshore wind farm, shall be marked with a yellow light. Additional turbines along the peripheral shall be marked, so that there will be a maximum distance between SPS defined turbines on 2 nautical miles.
- The yellow light shall be visible for 180 degrees along the peripheral and for 210-270 degrees for the corner turbines (typically located around 5-10m up on the transition piece). The light shall be flashing synchronously with 3 flashes per 10 second and with an effective reach of at least 5 nautical miles. Within the offshore wind farm the individual turbines will not be marked.
- A part of the top part of the foundation (e.g., the transition piece) must be painted yellow from from water level, High Astronautical Tide (HAT) up to a

[2] IALA Recommendation O-139 on The Marking of Man-Made Offshore Structures. Edition 2. December 2013 (IALA=Association Internationale de Signalisation Maritime)

height of 15 meters above HAT. Each turbine should be numbered (identification number) normally using of black number on a yellow background. Indirect light should illuminate the part of the yellow painted section with the turbine identification number.

- The marking of the individual offshore wind farm is expected to be synchronised with potential adjacent offshore wind farms.
- Requirements from the DMA for Racon (Radar Transponder) can be expected, depending on the exact location of the wind turbines.
- During construction the complete construction area shall be marked with yellow lighted buoys with a reach of at least 2 nautical miles. Details on the requirements for the positions and number of buoys shall be agreed with the DMA.
- In relation to shipping and navigation the marking and lighting requirements are independent of wind turbine size.

2.6.2 Aviation markings

Aviation markings must be approved by the DTA.

The standards and recommendations described below are specified in the guidance document BL 3-11[3] as well as in guidance material from DTA. For offshore wind farms with a turbine height above 100 m alternative measures may be agreed with the DTA. The BL 3-11 guide does not contain fixed regulations for aviation markings for turbines with heights above 150 m. This group of turbines must be approved individually based on site specific and safety issues. For these projects the aviation marking will generally be approved if they follow the guidelines in BL 3-11, which is summarized below.

For all offshore wind farms in Denmark the following standards apply:

- Blades, nacelle and the top 2/3 of the tower must be white/light grey (RAL 7035) according to CIE-standards (International Commission on Illumination).
- There must be a visibility meter for the light intensity and a measurement of the meteorological visibility, so that the light can be adjusted up and down depending on visibility.
- The light shall be visible from every direction 360 degrees horizontal around the nacelle, which most likely requires two lanterns to be installed on each nacelle.
- There shall be a light marking on the Tower structure

The offshore turbines relevant for Aflandshage Wind Farm all have a total height of above 150 m and the following standards apply according to the guidance document BL 3-11:

- Turbines placed in the corners and at sharp bends along the peripheral (significant peripheral structures = SPS) of the offshore wind farm, must be marked with medium intensity white lights, 20,000 candelas during daytime, and medium intensity flashing red light, 2,000 candelas during night time.

[3] Vejledning til BL 3-11. Bestemmelser om luftfartsafmærkning af vindmøller, 2. udgave maj 2018. Trafik-, Bygge- og Boligstyrelsen.

- Additional turbines along the peripheral, and inside the offshore wind farm area, shall be lit with fixed red light of low intensity (10 candelas as a minimum) day and night. The light shall be placed on the top of the nacelle and shall be visible from every direction 360 degrees horizontal around the nacelle, which most likely require two lanterns to be installed on each nacelle.
- As a standard requirement, the guidelines are valid if the distance between the turbines does not exceed 900 m. This distance will most likely be exceeded using the larger turbines, and therefore the final requirements for aviation marking must be agreed with the DTA in due time before construction. Most likely, it will be required that all the turbines along the peripheral of the offshore wind farm must be marked with medium intensity white lights, 20,000 candelas during daytime, and medium intensity flashing red light, 2,000 candelas during night-time (the same requirements as for turbines placed in corners and at sharp bends along the peripheral).
- Furthermore, a red solid light with an intensity of 32 candelas should be placed on an intermediate level (halfway between nacelle and mean sea level), at all turbines. Since the light should be visible from all directions, it will probably require min. 3 fixed lights (spacing of ≤120 degrees) at each turbine.

If cranes of 100-150 m height will be used during construction, these shall be marked with fixed red light of low intensity (10 candelas as a minimum).

2.7 Turbine installation

Although offshore contractors use varying construction techniques, the installation of wind turbines will typically require one or more jack-up vessel (Figure 2.2). Jack-up vessels have the ability of lowering legs onto – and into - the seabed and lift their hull out of the water and create a stable working platform. Alternatively, semi-jack-up vessels may be used (where the hull remains floating but is stabilized by posts or "spuds", lowered into the seabed), to ensure the stability required for the operation.

Figure 2.2: Turbine installation using a jack-up vessel. The illustration is not necessarily applicable to the current project where different solutions for foundation structures are included.

The wind turbine components will either be stored at the selected construction port and transported to site by support barge or by the installation vessel itself or transported directly from a port near the manufacturer to the offshore wind farm site by a barge or by the installation vessel. The wind turbines will typically be installed using multiple lifts, typically 5:

- Tower
- Nacelle, including hub
- Rotor blade x 3

Several smaller support vessels for equipment and personnel may also be required.

In calm weather conditions the main components of the current turbines can be installed in approximately one day (12 hours). The installation, however, is very weather sensitive due to the precise handling of wind-sensitive components at high elevations.

The duration of the entire turbine installation process for the offshore wind farm will thus depend on the season and weather conditions, and on the construction planning and strategy applied. Offshore construction operations are typically carried out 24 hours a day and 7 days a week to maximize the utilization of favourable weather windows and costly equipment and staff.

Following installation and grid connection, the wind turbines will be tested and commissioned, and the turbines will be available to generate electricity.

3 Foundations

In this chapter the technical descriptions for foundation solutions included in the project are described.

3.1 Foundation types

The wind turbines will be supported by foundations fixed to the seabed. It is expected that the foundations will comprise one of the following options:

- Steel monopile foundation
- Concrete gravity base structure (GBS)

These two types of foundations are relevant for all three alternative WTG types – small WTG, intermediate WTG, and large WTG solutions.

The dimensions and quantities given in this chapter are rough estimates based on experiences from similar projects and basic calculations for the purpose of being able to define worst case scenarios for the Aflandshage Wind Farm. It is not based on actual engineering or design works.

3.2 Monopile foundations

3.2.1 Description

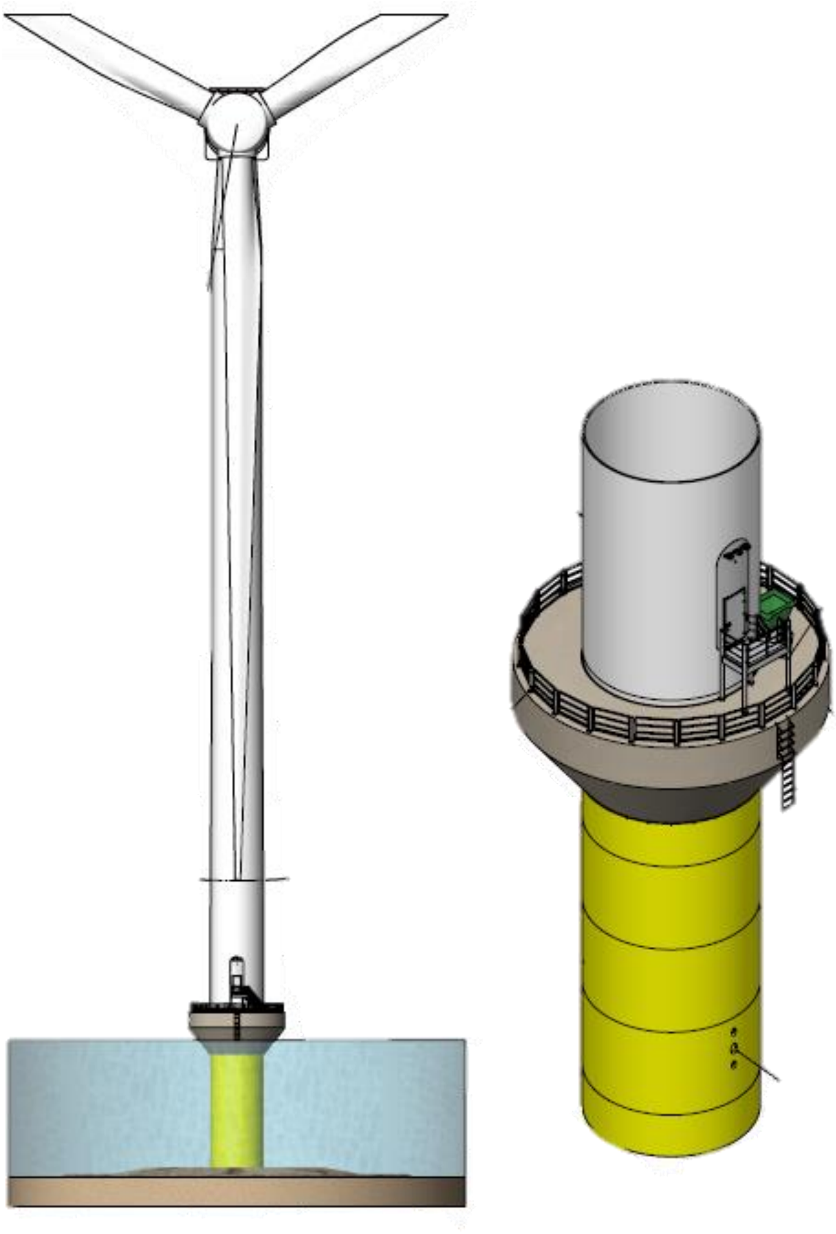
Monopile foundations are by far the most common type of foundation and have been used for 70-80 % of all offshore WTGs in operation today.

Monopile foundations primarily consist of a tubular steel structure which is driven into the seabed.

The foundation must – in addition to the WTG itself – support various secondary structures, such as platforms, ladders, boat landing, interface arrangements to array cables etc. These elements cannot be attached to the pile during driving, as the severe accelerations would damage them. To account for this, most of the monopile foundations include a transition piece – a steel sleeve, which is lowered over the pile and aligned to the required verticality. The annulus between the transition piece and the pile is then filled with grout. After the grout is cured, the cables and the WTG can be installed. The transition piece may also support the secondary structures.
In the recent years, other solutions than this grouted connection have been developed. These include a bolted flange connection between the pile and the transition piece and solutions not involving a transition piece – but with the secondary structures attached to the pile after installation, using brackets, bolting and clamping devices.

In Øresund the weather conditions are less harsh compared to more open waters and hence the service platform can be installed relatively close to the sea level. It is expected that the service platform will be attached to the transition piece if applicable or directly to the monopile.

Figure 3.1: Example of mono-pile transition piece with low interface level and WTG tower base. [4] *Possible yellow painting of tower up to 15 m above mean sea level is not shown.*



Monopile foundations are technically feasible in a wide range of soil types, from rather soft clays to softer rock types where it is possible to drive the piles into the seabed. If the soil is harder or if boulders do now allow of pile driving, drilling may be applied – typically as a drive-drill-drive solution. Alternatively, the pile can be installed in a pre-drilled hole and secured through grouting. Hence, harder soils or rocky underground may make monopile foundation a less obvious foundation solution. It must be noted that any kind of drill solution will cause some sediment spill in the sea. Further it may be expected that the soil drilled out may be transported by split barge and deposited at a dumping area offshore.

[4] HOFOR A/S October 2020, Nordre Flint and Aflandshage Concept Design Report. Illustration courtesy of Rambøll.

3.2.2 Grouting

Grouting might be used to fix transition pieces to the monopile, to connect the service platform to the monopile or transition piece, and to fix the pile to the drilled socket in case of pre-drilled monopiles. Grout is a cement-based product, used extensively for pile grouting operations worldwide. Grout material is like cement and according to CLP (Classification Labelling and Packaging) it is classified as a dangerous substance to humans (H315/318/335). The core of grout material (e.g., Densit® Ducorit® or BASF MasterFlow®) is the binder. The binder is mixed with quartz sand or bauxite in order to obtain the strength and stiffness of the product. The grout normally used would conform to the relevant environmental standards.

The grout will either be mixed in large tanks onboard the installation vessel, or mixed onshore and transported to site.

Methods will be adopted to ensure that the release of grout into the surrounding environment is minimized. However, some grout may be released as fugitive emissions during the process. A worst-case conservative estimate of 5 %, is assumed for the complete project.

3.2.3 Dimensions

Monopiles are typically designed individually to account for the physical conditions, i.e soil conditions and water depth etc. at the exact position where it is going to be installed, as well as the currents, wave climate, ice conditions at the site – in addition to the WTG loads. Subsequently, the dimensions are very much dependent on the actual conditions.

The diameter of the top of the monopile foundation will have to fit the WTG tower, unless a transition piece is used, in which case the top of the transition piece will have to fit the WTG tower. Larger pile diameters may be required and if so, a conical section is used to secure the fit of diameter to the WTG tower. The larger diameters would be increasingly relevant for larger turbines, deeper water and softer soil.

The monopile foundations will be designed to each position and vary in dimensions, weight and penetration depth. The monopile foundation dimensions, weights and penetration depths are expected to be kept within what has been well proven on other offshore wind farms.

Table 3.1 below gives the estimated dimensions for small, intermediate, and large WTG's for water depths ranging between 5 and 25 m.

Table 3.1: Estimates of monopile dimensions for the three alternative WTG sizes: small WTG (5.5 – 6.5 MW), intermediate WTG (7.5 – 8.5 MW) and large WTG (9.5 – 11.0 MW).

Monopile			
Turbine capacity	**Small WTG 5.5-6.5 MW**	**Intermediate WTG 7.5-8.5 MW**	**Large WTG 9.5-11.0 MW**
Turbines, #	45	31	26
Diameter at seabed level, m	4.5-7.0	5.5-8.0	6.0-9.5
Pile Length, m	40-65	50-70	50-80
Weight (excluding ice-conus), t	300-600	450-700	550-750
Ice-conus, t	450-1,000	450-1,000	450-1,000

Monopile			
Penetration depth (below the mud line), m	16-31	18-34	20-39
Total pile weight at 45/31/26 turbines (excluding ice-co-nus), T	13,500-27,000	13,950-21,700	14,300-19,500
Transition piece			
Length, m	10-16	10-16	10-16
Outer diameter (based on a conical shaped monopile), m	4.0-6.5	5.0-7.0	5.5-7.5
Outer diameter (in-cluding platform), m	9-15	9-15	9-15
Weight, t	100-350	100-350	100-350
Volume of grout per unit, m^3	20-40	25-60	30-65
Total transition piece weight at 45/31/26 turbines, T	7,200-11,700	6,200-11,470	6,500-10,920

3.2.4 Scour and scour protection

Scour protection, section 3.5, is typically made by placing stone material around the foundation. In some situations, it can be feasible not to install scour protection and instead include measures in the foundation design and cable protection systems to compensate for scour holes.

The decision on the approach is dependent on the extent to which scours are expected to form – which depends on the current and wave activity around the foundation and on the properties and mobility of the top layers of the seabed.

It is expected that scour protections will be used at Aflandshage Wind Farm, but it could be deemed feasible to omit scour protection, subject to the detailed site conditions.

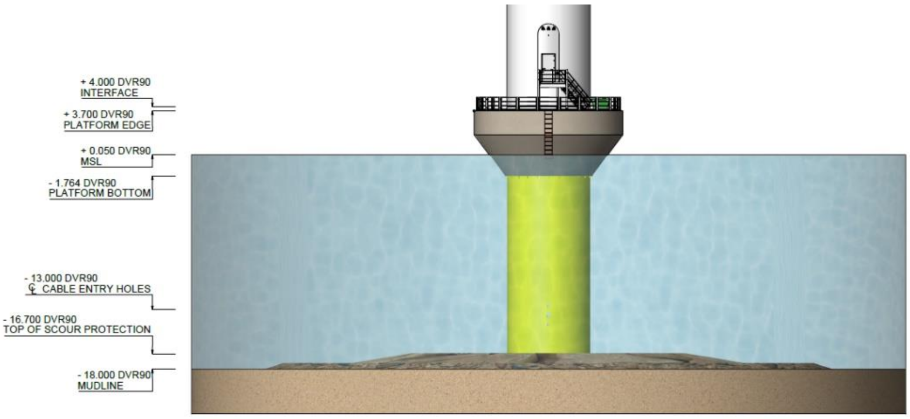


Figure 3.2: Principal sketch of a monopile foundation with low interface level and scour protection.[5]

In Table 3.2 the estimated extent and quantities of typical scour protection systems for monopiles are shown. The measurements and quantities are rough estimates, as it varies significantly according to the site-specific issues as well as installation methods used.

Table 3.2: Estimates of scour protection extent and quantities.

Scour protection			
Turbine capacity	**Small WTG 5.5-6.5 MW**	**Intermediate WTG 7.5-8.5 MW**	**Large WTG 9.5-11.0 MW**
Turbines, #	45	31	26
Volume per foundation, m^3	1,150-2,000	1,350-2,300	1,600-2,700
Footprint armour layer[6] per foundation, m^2	500-900	600-1,050	700-1,200
Footprint Filter layer[7] per foundation, m^2	600-1,000	700-1,150	800-1,350
Total scour protection volume at 45/31/26 turbines, m^3	51,500-90,300	41,700-72,200	40,500-69,500
Total footprint at 45/31/26 turbines, m^2	25,800-45,200	20,800-36,100	20,300-34,700

3.2.5 Ice deflection cone

The monopile foundations pile may be equipped with an ice deflection cone with the purpose of breaking drifting ice impacting the foundation. The ice cone will be designed to the local conditions.

3.2.6 Corrosion preventive measures

The steel structures will be protected against corrosion by means of coating and likely cathodic protection. In the case of cathodic protection a protective current is

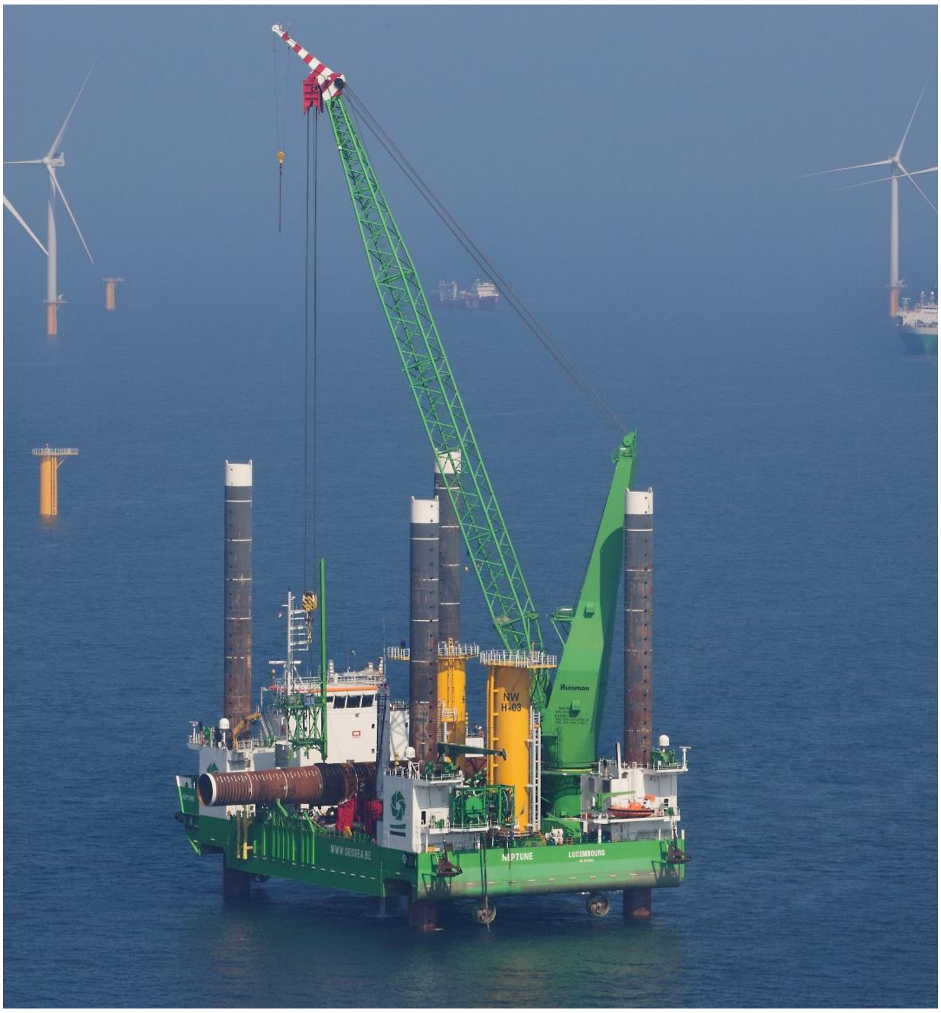
[5] HOFOR A/S October 2020, Nordre Flint and Aflandshage Concept Design Report. Illustration courtesy of Rambøll.
[6] Armour layer is the upper layer of scour protection comprising of larger stones sizes.
[7] Filter layer is a layer of smaller size of gravel stones placed on the sea bottom surface and below as basis for the armour layer of the scour protection.

induced, either by equipping the steel structures with sacrificial anodes (galvanic anodes) or by using an impressed current. A combination of the mentioned protective measures can be used.

3.2.7 Installation

The installation of the monopile will involve either a jack-up vessel or floating vessel stabilized by several anchors, equipped with a crane, a pile gripper and possibly pile tilting equipment. In addition, drilling equipment is expected to be included for the positions where the soil conditions require drilling.

Figure 3.3: Jack-up installation vessel. The illustration is not necessarily representative.



Support vessels, barges, tugs, safety vessel and personnel transfer vessel may also be required.

The expected time for driving each pile is between 4 and 6 hours, but this may be extended significantly due to soil conditions or weather conditions.

Installation of one foundation including the service platform and transition piece is expected to take around 30 hours not including weather downtime and transport. Due to local challenges some positions might take significantly longer than this.

The pile installation involves driving the pile into the seabed using a hydraulic hammer, and for some positions it is expected that drive-drill-drive of pre-drilling will be required. The hammer type and size, the size of the pile and the soil properties influences the number of blows and time required to achieve the target penetration depth. The hammer typically delivers 30 to 50 blows per minute, dependent on size and type. Table 3.3 provides possible pile driving scenarios for the three different monopile dimensions.

Table 3.3: Pile driving scenario for the three different monopile dimensions related to the three alterative WTG sizes: Small WTG (5.5 – 6.5 MW), intermediate WTG (7.5 – 8.5 MW) and large WTG (9.5 – 11.0 MW).

	Scenario 1	Scenario 2	Scenario 3
Turbine capacity	Small WTG 5.5 – 6.5 MW	Intermediate WTG 7.5-8.5 MW	Large WTG 9.5 – 11 MW
Pile maximum diameter at seabed level (m)	7.0	8.0	9.5
Penetration depth (below the mud line), m	16-31	18-30	20-39
Number of piles	45	31	26
Pile driving sequence			
Hammer Energy (force)	3,500 kJ	4,000 kJ	4,000 kJ
Number of pile strikes	7,000	8,000	8,000
Strike rate - ramp up phase	15 strikes pr. minute	15 strikes pr. minute	15 strikes pr. minute
Strike rate - full force	30 strikes pr. minute	30 strikes pr. minute	30 strikes pr. minute

The installation of a pile can be expected to require 7,000 to 8,000 hammer blows depending on the diameter of the monopile. Often the top layers of seabed soil are relatively soft, and it must be expected that the blow count per meter is the lowest and the penetration achieved per hammer blow is the highest early in the process. Even if the deeper soil layers are soft the friction between the pile and the soil increases with depth. Subsequently the advance per blow decreases. Towards the end on the driving process, the advance of 1 m of penetration may require approximately 200 blows.

Pile driving is often initiated with a soft start/ramp up phase, that will vary depending on the pile driving location as well as the size of monopile, hammer energy, number of pile strikes and the strike rate. An example of a standardized soft start/ramp up phase for the suggested monopiles is described in Table 3.4. Terms will be regulated by guidelines.

Table 3.4: Standardized soft start/ramp up phase for monopile installation

Amount of pile strikes (% of total number of pile strikes)	Force (% of full hammer energy)	Strike frequency (number of strikes pr. minute)
2	10	15
1	20	15
1	40	15
1	60	15
1	80	15

Amount of pile strikes (% of total number of pile strikes)	Force (% of full hammer energy)	Strike frequency (number of strikes pr. minute)
94	100	30

It will be important that only the appropriate driving energy and force is applied. If excessive force is applied the pile may buckle or experience fatigue damage. Subsequently, if the advance slows down and the pile refuses to penetrate further or advance slows down significantly before full penetration is achieved (due to hard soil layers or boulders) it may be necessary to use drilling equipment to drill out the soil inside the pile to penetrate or remove the obstruction before pile driving is resumed. Some positions are expected to require pre-drilling, in which case a socket would be drilled before installation of the pile.

The top layer of the seabed within the project area consists mainly of sand and mud. At a depth of 5-15 meters below seabed level within the project area, there is a limestone layer (GEO, 2019), where it can be necessary to drill out the material if monopiles are used. The amount that needs to be removed by drilling depends on the softness of the chalk. It is however assumed that 100 % of the material inside the pile will be removed when drilling is necessary and suspended and disposed of within the offshore wind farm area. Installation of monopiles may include drilling through the limestone layer. Table 3.5 provides estimated amount of material to be removed and suspended for the different scenarios.

Table 3.5: Maximum design scenarios for sediment release by drilling turbine monopiles.

	Maximum diameter of monopile (m)	Penetration depth (m)	Total volume of drill arising from one monopile (m^3)	Total volume of drill arising from all turbine monopiles (m^3)	Work and other assumptions
Scenario 3 (~10 %)	9.5	39	2,763	8,289	Up to 3 of the 26 turbines will be fully drilled
Scenario 3 (~25 %)	9.5	39	2,763	16,579	Up to 6 of the 26 turbines will be fully drilled
Scenario 3 (~50 %)	9.5	39	2,763	33,156	Up to 12 of the 26 turbines will be fully drilled

The seabed material removed from inside the piles during the drilling is typically disposed of within the offshore wind farm area, adjacent to each location from where the material was derived, where it is dispersed by current and waves. If this cannot be allowed, the soils can be collected and disposed of at an appropriate disposal site.

3.3 Gravity base structures (GBS)

3.3.1 Description

A gravity base structure (GBS) is a support structure held in place by gravity. GBS foundations have been used for offshore wind farms in Northern Europe. GBS foundations are suitable for reasonably firm seabed conditions and are especially relevant in case of relatively larger ice loads.

Two basic types have been used: 1) the flat base, open caisson type and 2) the conical type. It is expected that the flat base, open caisson type is the most feasible type for the Aflandshage Wind Farm due to the relatively shallow water depths, but the conical type might become relevant, subject to the detailed design.

3.3.1.1 Flat base, open caisson GBS

Flat base, open caisson GBS foundations have been used for several offshore wind projects.

This type of foundation consists of a base plate with open ballast chambers and a central column onto which the WTG tower or transition piece is bolted. After the structure is placed at the desired position the chambers are filled with ballast.

Open caisson GBS foundations require a relatively firm sediment base, and for several projects removal of soft sediment has been required. A GBS foundation does not require piling and can be considered when traditional piling is not possible, e.g., when the seabed is hard or rocky.

The foundation type is suitable at water depths up to approximately 20-25 m. Larger WTGs will likely make open caisson GBS foundations increasingly heavy and bulky.

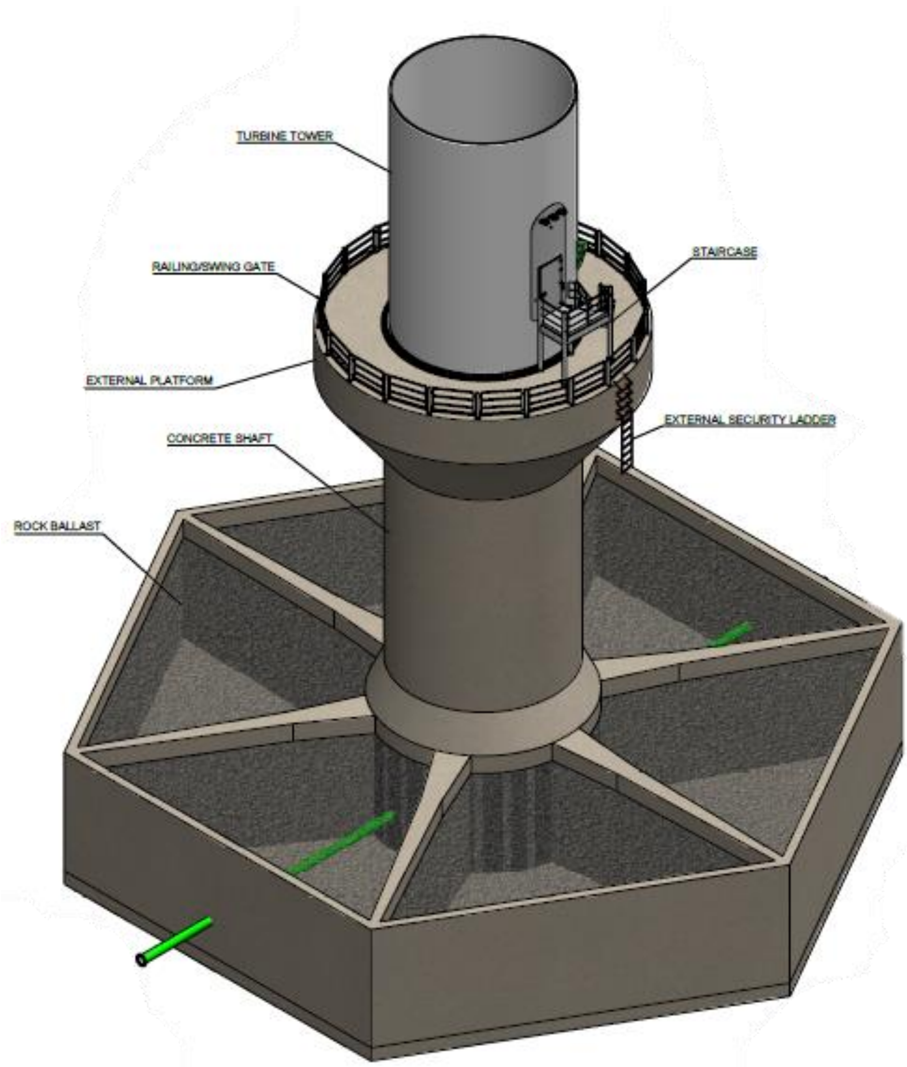


Figure 3.4: Principal sketch of an open caisson GBS foundation.[8]

3.3.2 Seabed preparations

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

- The top surface of the seabed is removed to a level where undisturbed sediment is found, using suitable dredging equipment (Suction, backhoe, grab), with the material loaded aboard split-hopper barges for disposal
- A gravel or stone bed is placed in the dredged hole to form a firm and level base.

The quantities for the seabed preparation depend on the soil conditions and design. Table 3.6 provides an estimate of quantities for an average excavation depth

[8] HOFOR A/S October 2020, Nordre Flint and Aflandshage Concept Design Report. Illustration courtesy of Rambøll.

of 2 m. Dimensions of GBS foundations to be placed in the excavations are given in Table 3.7.

The approximate duration of each excavation of average 2 m depth from sediment surface is expected to be 2 days, with a further 3 days for placement of the gravel/stone bed. The durations might be significantly longer, subject to weather conditions and local soil conditions

Depending on the type and quality of the soil removed, it can in the best cases either be used as backfill after the structures are in place or as fill material for other construction projects. Should beneficial use not be feasible, the material will be disposed of at sea at a registered disposal site.

There is likely to be some release to water from the material excavation process. By use of backhoe dredger a conservative spill rate of 5 % can be expected[9]. Jetting will activate all the material in the trench i.e. 100 % spill but the heavier fractions of the sediment will settle in the trench or close to the edge of the trench. An estimate by use of jetting will be a spill of 10 – 20 % equivalent to the fraction of the finest sediments (grain size < 0,145 mm).

Table 3.6: Estimates of excavation quantities, GBS foundations.

Gravity base			
Turbine capacity	**Small WTG 5.5-6.5 MW**	**Intermediate WTG 7.5-8.5 MW**	**Large WTG 9.5-11.0 MW**
Size of excavation, m (approximate diameter)	23-33	25-45	26-50
Material excavation, m³ (per foundation)	1,200-1,800	1,400-2,500	1,600-3,200
Gravel bed, m³ (per foundation)[1]	115–1,000	130-1,400	160-1,700

[1] Based on a gravel bed thickness of 0.3 – 1 m

3.3.3 Dimensions

As the name gravity base structure implies, these foundation types rely primarily on its mass to counteract the overturning moment generated by the WTG, and there is a direct link between the size of the WTG and the size and mass of the required foundation, however, issues such as water depth, ice and wave climate are also important factors. Furthermore, Installation vessel constraints can pose limitations to the GBS geometry.

Table 3.7 shows rough estimates of the size and mass of GBS foundations.

Table 3.7: Estimates of size and mass of GBS foundations.

Gravity base			
Turbine capacity	**Small WTG 5.5-6.5 MW**	**Intermediate WTG 7.5-8.5 MW**	**Large WTG 9.5-11.0 MW**
Turbines, #	45	31	26
Shaft Diameter, m	5.0-6.5	5.5-7.0	6.0-7.5
Shaft diameter (including platform), m	10-15	10-15	10-15

[9] Lorentz, R. Spill from Dredging Activities. Øresund Link Dredging & Reclamation Conference, pp. 309-324, May 1999.

Gravity base			
Base Diameter, m	23–30	25-35	26–40
Concrete mass per unit, t	2,000-4,200	2,300-5,000	2,500-5,000
Ballast, m^3	1,700-3,000	2,000-4,000	2,500-5,000
Total concrete weight at 45/31/26 turbines, t	90,000-189,000	71,300-155,000	65,000-130,000
Total ballast volume at 45/31/26 turbines, m^3	76,500-135,000	62,000-124,000	65,000-130,000

The central column may be equipped with an ice deflection cone with the purpose of breaking drifting ice impacting on the foundation (Figure 3.5). The ice cone will be designed to the local conditions.

Figure 3.5: GBS foundation with ice deflection cone.

3.3.4 Ballast

For the open caisson GBS foundations the likely ballast material is sand or rocks or a combination. The ballast will typically be quarried on-shore and transported to the site by transport vessels/barges and placed by excavators or using telescopic fall-pipe. The central column may be filled with sand/gravel as ballast.

3.3.5 Scour protection

Scour protection, see section 3.5, is likely to be required.

Figure 3.6: Principal sketch of an open, flat base GBS with scour protection. [10]

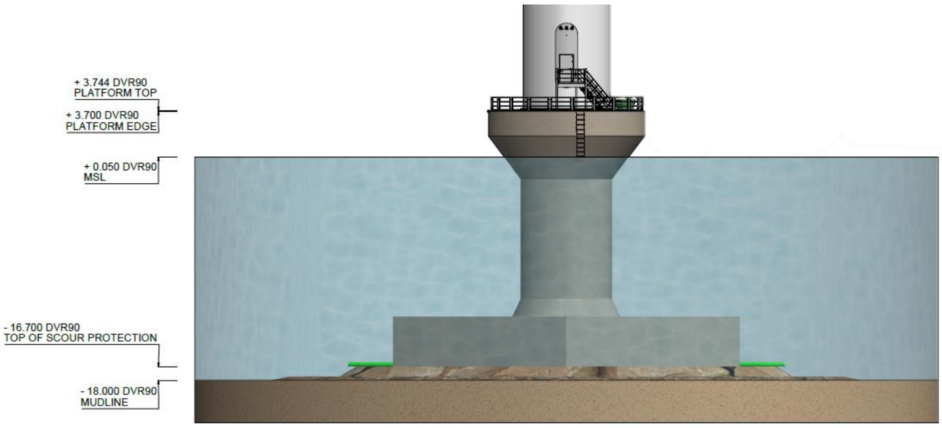


Table 3.8 shows a rough estimate of quantities. The basis for the estimate is the radius of scour protection being 5 to 10 m wider than the GBS base radius. The required scour protection will be highly dependent on the design and the actual geotechnical conditions. The quantities estimated do not include filling up scour holes already developed or installation tolerances.

Table 3.8: Estimates of GBS scour protection.

Gravity base			
Turbine capacity	**Small WTG 5.5-6.5 MW**	**Intermediate WTG 7.5-8.5 MW**	**Large WTG 9.5-11.0 MW**
Turbines, #	45	31	26
GBS base diameter, m	23–30	25-35	26–40
Diameter of base including scour protection [1], m	33-50	35-55	36-60
Scour protection volume per foundation[1], m^3	880-2,500	940-2,850	970-3,150
Total scour protection volume at 45/31/26 turbines, m^3	39,600-113,100	29,200-87,650	25,300-81,700
Total footprint at 45/31/26 turbines, m^2	38,500-88,350	29,850-73,650	26,450-73,500

[1] Depending on design and the actual geotechnical conditions

[10] HOFOR A/S October 2020, Nordre Flint and Aflandshage Concept Design Report. Illustration courtesy of Rambøll.

3.3.6 Corrosion preventive measures

The steel structures will be protected against corrosion by means of coating and likely cathodic protection. In the case of cathodic protection a protective current is induced, either by equipping the steel structures with sacrificial anodes (galvanic anodes) or by using an impressed current. A combination of the mentioned protective measures can be used.

3.3.7 Installation

The installation of the concrete gravity base will likely take place using a floating crane or crane barge with attendant tugs and support craft. The GBS is transported to site on a barge or a semi-submergible barge, or directly on the installation vessel. The structures will then be lowered onto the prepared gravel bed and ballasted. Then the scour protection is installed.

Figure 3.7: GBS installation from a flat top barge using a floating crane.

3.4 Secondary structures

Both the monopile and the gravity base structure foundations will require the following ancillary features for safety and operational protection of equipment:

- Access arrangement including boat landing for crew access/equipment transfer
- Service platform
- Array cable arrangement
- Corrosion protection
- Internal secondary structures in foundation and transition piece if applicable
- Various other secondary structures

3.4.1 Access platform arrangements for crew access/equipment transfer

The access arrangement typically comprises either boat landing or an arrangement to access the foundations directly at the service platform. At various points around the access arrangement and external platform hook-on points and fall arrest systems are placed for the crew's safety harness to be attached. Additionally, a safety ladder to access the foundation from the water is expected.

The access platform typically extends around the circumference of the turbine tower base and includes a lay-down area sufficiently large and sufficiently braced to support the various turbine components during replacement. The platform will be surrounded by a railing. The lay-down area might be provided by a temporary platform, that will be attached to the foundation when required.

The base of the platform may be made of concrete or steel. If concrete is used, this will typically also make up the platform deck, but if the platform is supported by a steel structure, the deck could also be made of grating to make the surface slip resistant, corrosion resistant, and of low weight.

3.4.2 Foundation cable routing

The cables by which the turbine is connected to the grid are typically located in a system of tubes on or within the foundation. The primary purpose is to protect the cable from the waves, currents and ice, but also to facilitate the installation of the cable.

Dependent on the foundation type, turbine type or seabed conditions, the tubes may be placed externally or internally on the foundations.

3.4.3 Corrosion protection system

Corrosion protection on the steel structure will be achieved by a combination of a protective paint coating and installation of sacrificial anodes or an Impressed Current Cathodic Protection (ICCP) system on the subsea structure.

All coating is done prior to installation, and only localized repair of the coating will take place after this. Application of corrosive protection paints will require staff to wear appropriate protective equipment.

The sacrificial anodes are standard products for offshore structures and are welded/clamped onto the steel structures. Even if GBS foundations primarily are made of concrete, a corrosion protection system can also be applied for this type of foundation, to protect the steel reinforcements and other steel components or as an indicator for corrosion. The number, size placement of the anodes is determined during detailed design.

Alternatively, ICCP system can be applied, consisting of anodes connected to a DC power source. The negative side is connected to the structure to be protected by the cathodic protection system and the positive side is connected to the anodes. ICCP system may provide a somewhat better control of the corrosion protection than the sacrificial anode-based system. However, a constant power source is required also until turbines are in operation and which must be maintained and monitored. Another advantage may be that the anode system will typically be less bulky.

3.4.4 Installation

The secondary structures may be installed at various stages of the foundation fabrication and installation process. Some secondary structures can be installed onshore, while others will be installed offshore, depending on the final design concept and whether a transition piece will be applied.

3.5 Scour protection

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

The description of scour protection in this section is relevant for both monopile and GBS foundation solutions.

Scour or erosion will occur when currents or waves accelerate the water flows around the foundation and the vertical velocity gradient of the flow is transformed into a pressure gradient on the leading edge of the structure. This pressure gradient produces a downward flow that impacts the seabed, forming a vortex which sweeps around and downstream of the foundation, and carries away sediment from the adjacent seabed.

Two different design approaches are typically applied to account for this:

- To install scour protection around the structure, typically by placing rocks around the foundation. This protects the soil and prevents it from being washed away and it continues to support the foundation. In the case of monopiles the scour protection might be installed before the installation of the monopiles if deemed feasible.
- To simply allow the scour hole to form, and to account for it in the design of the foundation by assuming a larger water depth and absence of the top layers of the soil

The latter approach will generally cause a pile to be longer and heavier. In some cases where the properties of the topsoil layer will allow a scour hole to develop, the soil may also have poor load bearing characteristics. In such cases the installation of scour protection will not have much effect on the size of the piles and can therefore be omitted.

The scour protection typically consists of a filter layer of stones followed by an armour layer of larger stones/rocks. Alternatively, a wide grade geometrical open single layer.

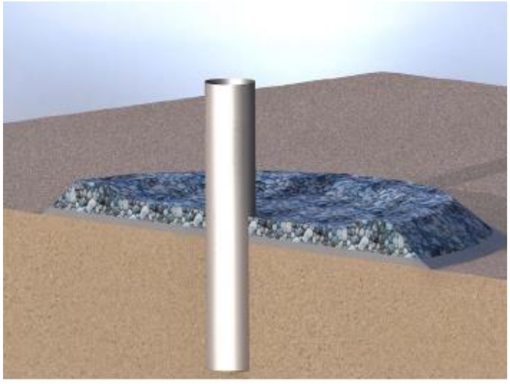


Figure 3.8: Principal sketch of scour protection around a monopile.[11]

3.5.1 Installation

If scour protection is required, the protection system normally adopted consists of rock placement. The rocks will be graded and loaded onto a suitable rock-dumping vessel at a port and installed from the vessel either directly onto the seabed from the barge, by a grab or via a telescopic tube (fall pipe).

3.5.2 Alternative scour protection measures

An alternative scour protection system is the use of sand filled geotextile bags around the foundations. This scour protection system will be used if deemed more feasible than rock scour protection. The volumes will be within the same range as a rock scour protection.

[11] Energinet April 2015, Technical Project Description for Offhore Wind Farms (200 MW). Offshore Wind Farm at Vesterhav Nord, Vesterhav Syd, Sæby, Sejerø Bugt, Smålandsfarvandet and Bornholm. Illustration courtesy of Rambøll.

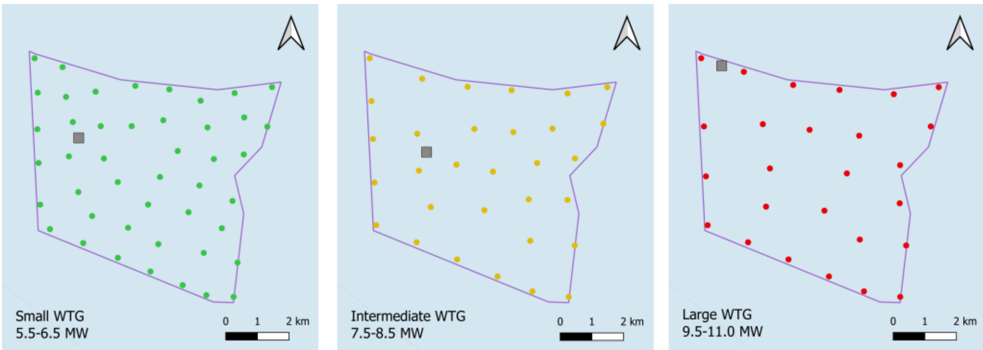
4 Offshore substation installations

4.1 Offshore substation platform

Offshore substations — the systems that collect and export the power generated by turbines through specialized submarine cables — are an essential component of offshore wind farms, especially at large, multi-megawatt sites. These systems serve an important function: to stabilize and maximize the voltage of power generated offshore, reduce potential electrical losses, and transmit electricity to shore. The exact location of the offshore substation will depend on the wind turbine capacity. Generally, it will be centrally placed relatively close to the cable corridor for the export cable, in order to serve as a hub for the array cables between the wind turbines and the export cable transmitting electricity to shore (Figure 4.1).

The platform consists of at topside and a foundation. The foundation will in this case be a monopile or gravity based structure, similar to the foundation of the wind turbines. Except that there will be 4-8 J-tubes for the array cable installation and one for the export cable.

Figure 4.1: Possible locations of offshore substation at Aflandshage (grey squares) shown together with the small turbine (left), the intermediate turbine (middle), and the large turbine (right).



The offshore substation will be fabricated and finalised on a yard and sailed to its final position ready for instalment. The installation is done by a special vessel. Installation time is approximately 1-3 days. The fabrication time (yard side) is normally approximately 2 years.

4.2 Topside design

The topside will consist of four decks.

- Cable deck
- Utility deck
- Main deck
- Top floor (roof deck)

The cable deck will primary be used for routing the array cables and for routing the export cable to the final connection points.

The decks will house the following equipment:

- High and medium voltage switchgear
- Main transformer
- Low voltage auxiliary supply system
- Backup power (diesel gen-set)

- Protection and control systems
- Pollution prevention system
- Firefighting system
- HVAC system
- Communication and IT system
- Platform identification system
- Aviation system
- Material handling system (Lay down area)

The estimated weight of the topside is 950 - 990 Tons. The footprint is expected to be approximately 20 x 24 m and the total height of the topside (excluding the foundation height) is expected to be approximately 19 m.

Table 4.1: Estimated total amounts of liquids and gasses.

Equipment	Type	Estimated Amount (kg)
High Voltage Switchgear	Oil for 33 kV	68
	Oil for 66 kV	390
	Oil for 132 kV	110
Main Transformer	Oil in tank	63,000
	Oil in coolers	6,900
Auxiliary Transformers	Oil in tank and coolers	1,350
Backup Supply Diesel Gen-Set	Diesel oil day- and storage tank	7,000
Firefighting	30 bottles of Argonite	930

4.2.1 High voltage and medium voltage system

The MV (medium voltage) cable system consists of MV cables connecting the MV switchgear and the main transformer, as well as cable from the MV switchgear to the auxiliary transformers.
The HV (high voltage) cable system consists of HV cable from main transformer to the HV switchgear.

The main transformer system consists of one oil-immersed 3-winding transformer. The transformer will be installed indoors on the main deck, whereas the coolers, will be placed outside. The main transformer is connected to the HV-GIS, and MV-GIS by cables designed to carry a worst-case load. It will be installed on the main deck in a naturally ventilated room with openings at lower and upper part of the room.

In order to reduce the noise penetration from the transformer to the platform, the main transformer will be placed, on the floor-level, on an anti-vibration system. A drip tray is placed below the main transformer for collecting any possible leaking oil from the transformer. The drip tray has the capacity to contain all the oil from the transformer and cooler banks.

The MV distribution system consists of a gas insulated MV switchgear (GIS). It will be installed on the main deck and serve as the entry point of the array cables from the offshore wind farm to the transformer platform. The MV switchgear is a combination of electrical disconnector switches and circuit breakers. The main function of the switchgear is to interconnect the array cables, the auxiliary transformers, and the main transformers. Via the MV switchgear it is possible to disconnect cables and equipment from the power system.

The auxiliary transformers will be connected, and power supplied from two dedicated MV bays in the MV switchgear.

4.2.2 Low voltage system

The LV (low voltage) systems are mainly providing utility power to the offshore substation at 400/230VAC normal supply, 400/230VAC Uninterruptible Power Supply (UPS), 220VDC supply, and lighting and small power supply during normal and emergency conditions.

The main supply system will consist of two normal supply switchboards. These two switchboards are supplied by the auxiliary transformers and will feed the normal lighting and small power, HVAC loads, crane loads, heat tracing loads, panel utility loads and UPS & DC system loads during normal operation.

When the platform is running in island mode (no grid voltage available), the switchboards will be supplied from the auxiliary/emergency generator.

The switchboard distribution system feeds a fully redundant 400/230VAC or 220VDC distribution system supplied from the AC or DC UPS's and distributing emergency power to SCADA (Supervisory Control And Data Acquisition), protection, telecom, HV/MV/LV switchboards and emergency lighting.

Both systems will individually have sufficient rating to supply full control voltage to all essential loads requiring UPS power.

All areas will be provided with lighting systems consisting of main lighting and emergency lighting. Normally, the main and emergency systems will operate to maintain the required illumination level.

In case of main power failure, the auxiliary/emergency generator will start up and supply the lighting system for at least 18 hours.

If both main and diesel supplies fail, the emergency light (30% of all light fixtures) will be supplied from the UPS system. The UPS transition power will last for at least 10 hours.

4.2.3 Lightning protection system

The lightning protection zones (LPZ) shall be identified by the rolling sphere method according to the standard.

The topside structure will be an integrated part of the lightning protection system and use metal structures as conductor.

Dangerous sparking and transients can be avoided by bonding conductors or by installing a surge protection device.

4.2.4 Diesel generator system

Two permanent back-up generators are installed on the platform, one as duty and another as standby generator. In case of power failure in the low voltage system on the OHVS (offshore high-voltage station), the duty generator will automatically start up to supply power for the UPS systems and critical consumers which are not

UPS fed. In case the duty generator fails to start, then the second generator (standby) will attempt to start and feed the LV panel.

To store and supply the back-up generators with the required amount of fuel, a dedicated fuel system will be installed.

The rated power of each generator shall be able to feed the low voltage part as a back-up generator.

The diesel generator system will be manufactured for standard industrial operation and shall operate at low sulphur marine diesel oil.

Each back-up generator will be built inside an acoustic enclosure steel rack construction with sound absorbing and thermal insulating mineral wool, protected by perforated sheet steel and suitable for indoor use. Each generator enclosure will be located in the dedicated diesel power room on the mezzanine deck. The following equipment will also be installed in the diesel power room; exhaust system including silencer, ventilation, control panel, and air in/outlet for combustion and cooling air to the back-up generator which will be mounted with vane separator in order to remove the majority of the liquid/moist/sea spray and salt aerosols.

The back-up generators will be able to synchronize with the main grid to perform load tests and maintenance.

The back-up generators can be used as temporary power supply for offshore installation and commissioning.

4.2.5 Diesel fuel system

The main purpose of the diesel fuel system is to keep the generators running by transferring diesel from the storage tanks to the two standby diesel generators.

The diesel fuel system consists of a storage tank, a diesel distribution pump which is a part of the diesel storage tank unit, and two day tanks installed inside the main diesel generator enclosure.

The diesel storage and transfer system consist of a 5 m^3 diesel storage tank, two fuel transfer pumps, filter and solenoid valve towards each diesel day tank.

The main diesel fuel storage tank will be sufficient for 10 days of operation for one standby diesel generator. The storage tank is double walled, with connections for the mobile storage tank for refilling.

The day tank is built into the frame of the diesel generator and has a capacity of 0.5 m^3. Each day the tank will be supplied with fuel by a dedicated diesel transfer pump.

4.2.6 Control and protection system

The SCADA (Supervisory Control And Data Acquisition) system will be a common SCADA system to monitor and operate all connected subsystems. The SCADA system will integrate signals from the substation protection and control equipment to the extent feasible for the operation of the substation from the SCADA HMI (Human Machine Interface). The SCADA components will be connected through a dedicated SCADA LAN (Local Area Networking) and will include data storage facilities.

The HMI for the substation SCADA system will include all relevant information to ease the operation of the substation and its auxiliary systems. The HMIs will contain overview screens showing the toplevel information with possibility to access further details for individual bays and components.

The data storage will make it possible to view historical data on the SCADA system HMI. This includes alarms, events, operations and measurement data. The resolution of measurement data depends on different attributes (threshold value, update interval etc.) The storage space of the SCADA servers will limit the possible size of the data archive.

The SCADA main equipment consists of all servers, HMI clients, gateways, network switches and other equipment relevant for generating HMIs including storage of data, alarm handling etc. The core system will be redundant to the extent feasible to ensure high availability. Consequently, the core system is designed in two separate parts working in a hot/standby configuration.

On each outgoing WTG feeders, one energy meter will be installed. The measured kWh and kVArh will be presented on the Platform SCADA HMI. Metering data shall be synchronized every quarter of an hour.

The protection system includes the MV protection relays installed in the LV compartment of the 33/66 kV cubicles plus main transformer protection system for 132 kV side including the main and backup relays, automatic voltage regulator (AVR) device and point of wave switching relay.

Interlocking will be implemented as hardwired and/or programmed logic in the protection relays for opening/closing of circuit breakers, disconnectors and earthing switches.

The relays will be equipped with supervision function to supervise the trip coils of the breakers and current transformer/voltage transformers circuits.

The control system has many signal interfaces to the auxiliary systems. For all auxiliary systems, the signal exchange is limited to key status information, alarms, measurements etc. and to signals relevant for the control of the systems below as typical.

- LV Switchboards, UPS, Battery Chargers
- Fire Alarm System and Fire Fighting Systems (Foam, Inert gas)
- Ventilation System
- Heating and Cooling System
- Drainage System
- Diesel Storage System
- Diesel Fuel System
- Diesel Generator System
- Access Control System (Manned/unmanned platform)
- Light Control
- PA/GA System (Public Address General Alarm)
- CCTV System (Closed-Circuit TeleVision)
- Misch. Telecom Systems
- NavAid System
- Platform ID System
- Environmental Monitoring System
- Bird Deterrent System

4.2.7 Access control system (ACS)

The access control system consists of two parts: the manned/unmanned function and the door position monitoring system. In general, the manned/unmanned function is used by the operator and/or staff entering or leaving the offshore platform to set the operation mode of relevant systems to manned or unmanned status. The door position monitoring system will monitor the state of each exterior door.

The main function of the door position monitoring system is to give an intruder alarm signal in the event of a door being opened when the platform is unmanned (unauthorised access to the platform). Secondly, the door position monitoring system is responsible for always monitoring the platform door positions to ensure that no doors are left open. An open door can have a negative impact upon corrosion protection and on the functionality of the fire extinguishing system.

4.2.8 Cyber Security system

The national requirements for implementing protection against intrusive dangers to the installation will be integrated. The requirements are typically set up as a combination of fixed and software based barriers. Backup and recovery philosophy add to minimised downtime in case of intrusion or general break down.

4.2.9 Firefighting system

The automatic fire detection and emergency shutdown system are designed for the offshore wind farm substation shall be a standard marine approved FAS (Fire and Alarm System) with addressable fire detectors intended for installation throughout the substation.

The indoor areas will be covered with smoke, heat and flame detectors. The detectors shall be interconnected to the same loop. The maximum number of detectors within a detection area will depend on the area to be covered by the detectors. However, a minimum of three detectors will be used in each detection zone.

At least two detectors need to be activated to trigger a ‘confirm fire’ status which the system recognises as a fire alarm and takes corresponding action to fight the fire.

Foam- and inert gas systems will be installed for firefighting.

The foam system is designed as a fire extinguishing system for rooms with oil-based components or/and non-sealed rooms.

The foam system is customised according to each application and area based on a modular design with a dedicated stand-alone unit protecting various areas. The piping system, used for delivering water to the foam nozzles, is designed to be dry until the system is activated.

The design is with 2x100% bank capacity on a common manifold. Only one bank can be connected to the manifold via manual isolation valves.

When the foam system is activated, compressed nitrogen is used as a propellant to pressurise the normally unpressurised water storage tank from where water will flow and, via inductor, mix with foam concentrate.

After release, the 300-bar propellant will pass through the main pressure-reducing valve and pressurise the water storage tank to approximately 10 bars.

At the same time, the release will initiate an actuator opening the distribution ball valve, thus releasing foam/water from the tank into the distribution pipe system. Finally, on site, the water/foam will be discharged through the foam nozzles positioned inside the protected areas.

If the fire control panel has been taken out of service, the CAFS (Compressed Air Foam System) unit can be manually released by operating the manual pneumatic actuator on the 'pilot' nitrogen cylinder and using the manual bypass on the pressure operated actuator on the water discharge valve in question.

The foam unit is based on the use of a water storage tank, an atmospheric foam tank, a foam inductor, a standard nitrogen cylinder bank, a main pressure-reducing valve station, a pilot pressure-reducing station, a diverter valve (one per area) and a set of foam nozzles.

The tanks will be equipped with level switches for monitoring the content of water and foam in the tanks (indication for tank full) and will also have weld-in site glasses for visually checking if tanks are full.

The trim for each area will be provided with a pressure switch installed upstream of the water discharge valve, enabling remote monitoring of the release. The indication of release is to be sent to the FAS (Fire Alert System) (SCADA). Each distribution valve is made without a position indicator and needs to be manually reset after a release.

The trim for each area will be equipped with a manually operated diverter test valve. The 'pilot' nitrogen cylinder is fitted with solenoid valves for automatic release via the fire alarm panel.

Low-expansion heavy foam is used for the application due to several factors. Based on a worst-case scenario, which would be a pool fire around the transformer, the heavy low-expansion foam will generate a complete shield covering the largest area over which oil is expected to spread. The heavy foam will prevent any oxygen from getting in contact with the burning oil. At the same time, the heavy foam will not be affected by the natural ventilation inside the transformer room compared to light foam.

Alcoseal will be injected from the foam tank into the system in a 3% water solution. The film forming fluoroprotein (FFFP) provides maximum protection against fires involving liquid hydrocarbon. Alcoseal is perfectly suitable for the extinguishing of burning transformer oil, also categorised as a class B fire.

The Alcoseal foam liquid is fully biodegraded within 21 days and has an exceptionally low aquatic toxicity. Furthermore, Alcoseal has a low human toxicity, a good film forming stability and 25% drainage time of 300 seconds.

Extinguishing with Inert Gas means reducing the oxygen content inside a room to the point where a fire can no longer burn, but without compromising the safety of the people who are present. There are no toxicological factors associated with the use of Inert Gas.

The Inert Gas system will be installed in room(s) dedicated for firefighting equipment and shall be dimensioned to cover the largest room once and shall have no redundancy.

The Inert Gas cylinders can also be released manually by removing a cutter pin and turning the handle on the manual release unit fitted on the master cylinder.

The Inert Gas cylinders are installed in a double configuration. The cylinders in the battery are connected to a common release manifold arrangement via high-pressure discharge hoses and a check valve assembly (one per cylinder). The check valves allow removal of one or more cylinders from the manifold without having a significant loss of Inert Gas through the connection point should there be a release of the remaining cylinders in the bank.

Inert Gas systems shall be monitored and controlled via the platform fire alarm and control panel (FAS). The room shall be evacuated prior to the release of gas in order to guarantee extinguishing effect and human safety.

The control panel can be equipped with a 20- to 60-second time delay (determined by the requirements of the authorities having jurisdiction).

The warning alarm and time delay will start simultaneously.

The release can be inhibited by operating the relevant ‘inhibit key’ switch in the dedicated fire zone. When operated, the inhibit function will prevent the automatic release. However, the cylinder bank can still be manually released at the manual call point.

4.2.10 Ventilation system

The ventilation system consists of two redundant units. The system is designed to provide ventilation by recirculation and supplying fresh, filtered and conditioned air into specific rooms on the substation and to create an overpressure in these rooms compared to outside to reduce the ingress of saltwater aerosols and dust particles into the building.

Air supply ducts have manual control dampers for balancing of airflows in rooms. Silencers will be installed in ducts when required by design in order to maintain the required noise level in rooms.

In case of fire in any substation room, the AHU (Air Handling Unit) shuts down and the fire dampers close.

The HVAC LV and Control System shall power, control and monitor the HVAC equipment, which is part of the ventilation system and heating and cooling system.

The Control System is responsible for ensuring the indoor temperature and air relative humidity meet the requirements for the rooms. Temperature/humidity transmitters and differential pressure transmitters installed in the rooms provide information to the Control System. The Control System then processes the information and adjusts the operating conditions of the ventilation system and heating and cooling system in order to maintain the required room conditions.

4.2.11 Navigation and identification

White lanterns for maritime marking of fixed offshore structures in accordance with international regulations.

An automatic identification system device serves to exchange navigation data between ships as well as between ships and stationary onshore/offshore stations via radios.

The visual night-time identification marking of the platform consists of 4 close-range illuminated name plates that can be read at night or during bad weather conditions. The name plates are installed on either side of the platform. The light system requires dedicated 96 hour backup power.

5 Cables/grid connection

5.1 Cables

Medium voltage inter-array submarine cables are expected to be connected to each of the wind turbines and for each row of 7-14 wind turbines depending on the size of the wind turbines (Table 5.1). With the basis in 33 kV cables with a conductor cross sectional area of up to 1200 mm^2 Cu or Al. The cables will be lead-free. Approximately 45 MW of wind turbines can be connected to each cable. 33 kV cables will only be relevant for the small turbines[12]. A possible layout of the 33 or 66 kV inter-array cable option for small turbines is shown in Appendix 2.

Table 5.1: Inter-array cable type for the three alternative WTG types.

	Small WTG 5.5-6.5 MW	Intermediate WTG 7.5-8.5 MW	Large WTG 9.5-11.0 MW
Inter-array cable type	33 or 66 kV	66 kV	66 kV

For the intermediate and large turbines 66 kV cables will be used when installing cables to the offshore wind farm. The 66 kV cables will be similar to the 33 kV cables but will have thicker isolation and are also expected to use an up to 1200 mm^2 Cu or Al conductor[13]. A possible layout of the 66 kV inter-array cable option for intermediate/large turbines is shown in Appendix 3. The 132 kV cable will only be used to connect the offshore substation to shore. Weight per kilometre for the different submarine cable types is shown in Table 5.2.

Table 5.2: Description and weight of the different submarine cables.

Type	Description	Weight (approx.)
33 kV submarine cable	300-1200 mm^2, Cu or Al conductor	45-65 t/km
66 kV submarine cable	300-1200 mm^2, Cu or Al conductor	50-70 t/km
132 kV submarine cable	1200-1600 mm^2, Cu or Al conductor	125 t/km

The distance between the cables leading from the offshore wind farm to shore should be no less than 3 times water depth and up to approximately 100 m if the width of the cable corridor allows it. The larger distance will reduce the risk of disconnecting the entire offshore wind farm as it reduces the risk of all cables being damaged simultaneously by e.g., a dragging anchor as well as providing ample space for any necessary repair actions.

Under certain conditions, where installation conditions are unusually complicated or certain vulnerable protected natural sites must be crossed, the distance between cables is typically 25 meters. At landfall the distance between cables can be reduced to approximately 5-10 meters. Estimated total lengths and weights for the layouts of the 33 kV and 66 kV inter-array cable option (with or without the offshore substation) for the small turbines are shown in Table 5.3, for the intermediate turbines in Table 5.4, and for the large turbines in Table 5.5. The grid connection distance from the inter-array cable jointing locations to landing of cables varies from approximately 15 to 20 km and are included in the total distances given in tables. With an onshore substation with the use of 33 or 66 kV offshore cables,

[12] SEMCO Maritime. Feed Study rev. A. Study report to HOFOR A/S
[13] SEMCO Maritime. Feed Study rev. A. Study report to HOFOR A/S

up to 6 parallel cables must be installed for grid connection. With an offshore substation (OSS) only one single 132 kV cable must be installed for grid connection with a length of approximately 18 km for the location of OSS in the small and intermediate WTG layout and approximately 16 km length for the location of the OSS in the large WTG layout.

Table 5.3: Estimated total lengths and weights for the different inter-array cable and grid connection options for the small turbines. Ranges are given for lowest possible weights with 33 kV cables to highest possible weights for 66 kV cables.

Small turbine 5.5-6.5 MW	Type			Weight (t) (approx.)
	33 kV (km)	66 kV (km)	132 kV (km)	
Onshore transformation	163	163	0	7,350-11,450
Offshore transformation	58	58	18	4,850-6,350

Table 5.4: Estimated total lengths and weights for the different inter-array cable and grid connection options for the intermediate turbines.

Intermediate turbine 7.5-8.5 MW	Type		Weight (t) (approx.)
	66 kV (km)	132 kV (km)	
Onshore transformation	103	0	5,150-7,250
Offshore transformation	48	19	4,800-5,800

Table 5.5: Estimated total lengths and weights for the different inter-array cable and grid connection options for the large turbines.

Large turbine 9.5-11.0 MW	Type		Weight (t) (approx.)
	66 kV (km)	132 kV (km)	
Onshore transformation	120	0	6,000-8,400
Offshore transformation	47	16	4,350-5,300

5.2 Installation of Cables

The submarine cables are transported to the site after cable loading in the load-out harbour at the factory. The cables will be placed on turntables on the cable laying vessel. The cable laying vessel may rely on tugs for propulsion, anchor wire pulled barge or can be self-propelled.

Figure 5.1: Cable in turn table aboard cable laying vessel.

All the submarine cables, both array and export cables will be buried at a sufficient depth to provide protection from fishing activity, dragging of anchors etc.

Depending on the seabed conditions the cable will be surface laid and post buried (jetted), simultaneously laid and buried (ploughed), installed in a pre-excavated trench or directly on the sea bottom and covered with rocks for protection, mattresses, stone bags or other remedial protection.

A burial depth of approximately 1.5 m must be expected. The final depth will vary depending on a more detailed soil condition survey, incl. geophysical survey[14] and the equipment selected. It can be expected that up to 10 % of the cable route will include cables installed on the sea bottom and protected by rock dumping or other means of protection like mats.

5.2.1 Pre-excavated trenches

The most likely installation method for subsea cables is expected to be in pre-excavated trenches. In case of hard soils such as stiff clay or compacted sand a trench can be made beforehand. Thereby the laying and the protection of the cable is split into two separate operations. With this method the cable is first placed

[14] Background report for geophysical mapping and characterization of the seabed. Aflandshage windfarm area. GEUS July 2020.

into the previously prepared trench into the seabed. After the cable has been installed in the trench the trench can be filled again with the excavated material, possibly with added stones or gravel or just left as is. In the latter case the optimum protection level is reached when the trench over time has filled itself.

The installation by excavation is quite costly compared to post lay jetting. The method with trenching by means of an excavator is suitable for installations below 18 m.

In order to be sure that the cable has reached the bottom of the trench it may be necessary to some extent to jet the cables with a jetting sled. This may be necessary if the trench has collapsed or filled with organic material.

The width of the trench in the seabed will be approximately 1-2 meters depending on the size of the grab on the excavator. Generally, the depth of the trench and the width of the trench may ideally be chosen as approximately identical as a wider trench needs to be deeper to provide adequate protection.

The pace of the trenching operation is depending on the seabed encountered. Generally, a progress of 100-1,000 m/day can be expected. The jetting operation that may follow the laying operation will be done in material that is already disturbed by the trenching and the rate of progress may be of 2,000-3,000 m/day.

5.2.2 Cable burial by Jetting

Water jetting is a cable burial method in which a device (usually a remote operating vessel (ROV)) equipped with water jets fed by high power water pumps liquefy the sediment below the cable, allowing it to sink to a specified depth (dependent on the penetrating length of the swords), after which coarse sediments are deposited. Cable jetting can typically be used in sediments such as silt, sand or peat.

Water jetting has become a frequently used power cable burial method. Typically, the submarine cable is buried after having been deployed on the seabed. The method is also often used to rebury repaired sections or old cables. Post-lay burial has the advantage that cable laying operations are not delayed if difficult burial conditions are encountered.

It is an effective method where a thick layer of soft sediments (silt) and/or sand are found in the seabed.

There are different types and sizes of jetting equipment. Some small water jetting machines usually have surface water pumps and need assistance from divers, and they are typically used in shallow waters. Larger jetting machines with on-board water pumps are often remote-controlled, and they can operate in deep waters.

The effectiveness of the cable protection depends not only on burial depth, but also on the amount of material that will be removed from the trench. The best protection is obtained if the trench is narrow and is filled with the original material immediately after the jetting operation. In some areas an open trench will be filled in a few days or weeks because of the natural current and tide and the transport of material in the waters. It is important to avoid a situation where the cable is jetted down to, typically, 1 m lying in a wide open trench without any protection because all material near the cable has been jetted away from the cable. The width of the seabed affected by the jetting operation itself will be approximately 0.7-1.2 m depending on the size of cable and the jetting equipment used.

The rate of progress, of the jetting operation, is depending on the seabed encountered. Generally, a progress of 500-2,000 m/day may be anticipated.

5.2.3 Cable burial by plough

Another cable installation method is by direct burial of the cable into the seabed. The cable is guided into a self-closing furrow cut by a sea plough towed by a surface vessel. This method requires homogeneous and softer soil conditions.

As a cable approaches the seabed, it is fed through the plough, which inserts the cable into a narrow furrow. Different plough designs are available to suit various bottom conditions, e.g., the traditional ploughshare is well suited for muddy substrates, whereas sandy sediments may require a plough equipped with water jets to cut a trench into which the cable is placed, thus reducing the needed mechanical power.

As a plough passes across the seabed, the share opens a furrow, inserts the cable and allows sediment to fall back, thereby filling the fissure. The precise nature of this disturbance will vary with substrate type, depth of burial and plough type. However, burial in more consolidated substrates may result in only partial closure of the furrow, with displaced sediment deposited at the furrow margins, which can be up to several tenths of cm high.

Ploughs are often used for burial of telecom cables and light weight power cables. It is also possible to use a large plough to bury and protect larger power cables, but this method entails some risks if it is not both designed and handled with great care. If the plough is not suitable or if it is not operated correctly, there is a risk to damage the cable it is supposed to protect. Especially if the seabed soil is inhomogeneous, or if the plough hits boulders, logs or other large, embedded objects, the plough can lurch, make a sudden sideway move and perhaps damage the cable.

The width of the seabed affected by the ploughing operation itself will be in approximately 1-2 meters depending on the size of cable and the equipment used. A pre lay grapnel run (PLGR) is performed before ploughing starts in order to remove unwanted objects.

The pace of the ploughing operation is depending on the seabed encountered and the exact equipment used. Generally, a progress of 100-2,000 m/day may be anticipated.

5.2.4 Vertical injector

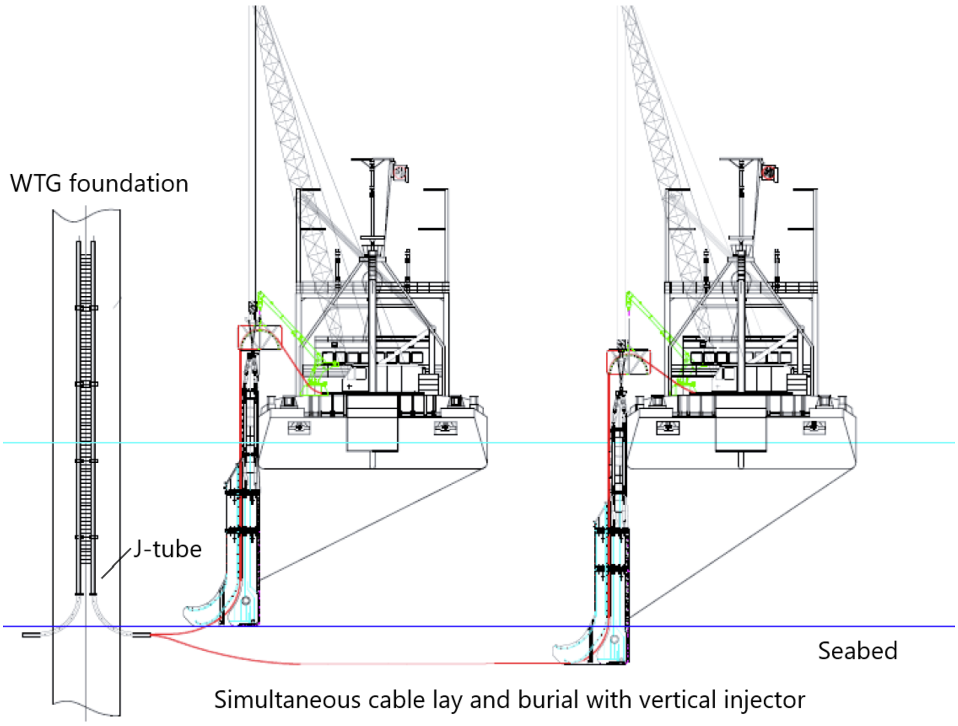
The vertical injector (jetting assisted plough) consists of a jetting head / sword with water nozzles on the leading edge. The cable is routed through the jetting head and thus the laying and protection is done in one operation. The method is widely used in Asia and in some European countries.

The method is well suited for deep installations in jet-able soils, where water depth is relatively shallow. However, the method is very time consuming and to some extent vulnerable to changes in weather. However, in case of severe weather the jetting head can be left in the seabed while the cable ship or barge is on weather stand-by.

The method is very suitable for deep installations of cable near shipping lanes and in harbours as the cables can be buried very deep.

The width of the seabed affected by the vertical injector installation and the rate of progress may be expected to be the same as the general ploughing operation mentioned earlier, i.e., 1-2 m width, 100-2,000 m/day progress.

Figure 5.2: Vertical injector (jetting assisted plough).[15]



5.2.5 Protection by rock cover

Rock cover as a protection method consists of covering the cable with regular rocks forming a properly designed berm. This application is widely used for sub-marine pipes.

Depth, wave action, sea current, rock size, berm side slope and height are the most important variables to design appropriate cable protection with rock cover. Rock sizes normally utilized vary from 10 to 40 cm, depending on the application.

Typically, an over-the-side rock placement vessel will be used. The rock is pushed overboard at a steady pace. This rock dumping method is typically used in shallow water. For deeper water a telescopic fall-pipe may be used. The width of the rock cover can be expected to be up to 9 m. The rate of progress of the operation will depend to great extent on the method used for covering the cables. A progress of 100-1,000 m/day may be anticipated.

A possible alternative to protection by rock cover is protection by mattresses or sandbags.

[15] Energinet April 2015, Technical Project Description for Offhore Wind Farms (200 MW). Offshore Wind Farm at Vesterhav Nord, Vesterhav Syd, Sæby, Sejerø Bugt, Smålandsfarvandet and Bornholm.

5.2.6 Installation of cables on low water depths

When installing sea cables, pipes for sea cables, preparing cable laying and any subsequent works, it may be necessary to use anchor operated barges in shallow water close to shore (approximately -6.0 m). Larger vessels with dynamic positioning systems cannot be used in shallow water.

The lay barges may as mentioned position themselves by anchoring. It is assumed that a barge must use a maximum of 6 steel anchors of approximately 2-5 tons each with 3 anchors at either side. Anchoring will be necessary 3-4 times per kilometer at low water depths. This corresponds to about 40 anchor positions to each side of the vessel from coast to about 3 km from shore. The anchors are connected to the barge with either a steel wire or an anchor chain. Each anchor wire/chain can have a length of up to 200-300 m depending on water depth, wind, wave height and sea current on that day. Anchor chains will temporarily lay on the seabed when positioning and repositioning the anchors as the barge moves, the anchor wire/chain will be pulled across the seabed at an angle to the anchor. The angle taken will not exceed 90 degrees. During the installation of the cables the wires will be tensioned and will not be located on the seabed.

Seabed intervention due to anchor handling is estimated to 5 m x 5 m pr. anchor corresponding to a maximum of 1,000 m^2 on each side of the cable corridor. Within the footprint of the anchor, it will be able to twist and move during the barge operation.

As the cable corridor is very narrow in some places close to shore, it may be necessary to place anchors temporarily outside it. The anchors will be moved regularly during the work by smaller anchor handling vessels, which will also sail outside the fixed cable corridor to either lay out or take in the anchors.

The anchors will, as far as possible be located outside the Natura 2000 area east of the cable corridor, but it cannot be excluded that up to 3 anchors for each position of the barge including chains will be placed in the area for the safe handling of the vessel/barge.

In cooperation with the selected contractor the anchor positioning will be optimized to locate anchors outside the Natura 2000 site. In situations where this cannot be avoided due to safety reasons the impacts from anchor locations will be minimized by selection anchor positions in the Natura 2000 site with less as possible impact on the vulnerable areas and trying to reuse anchor positions when moving the barge.

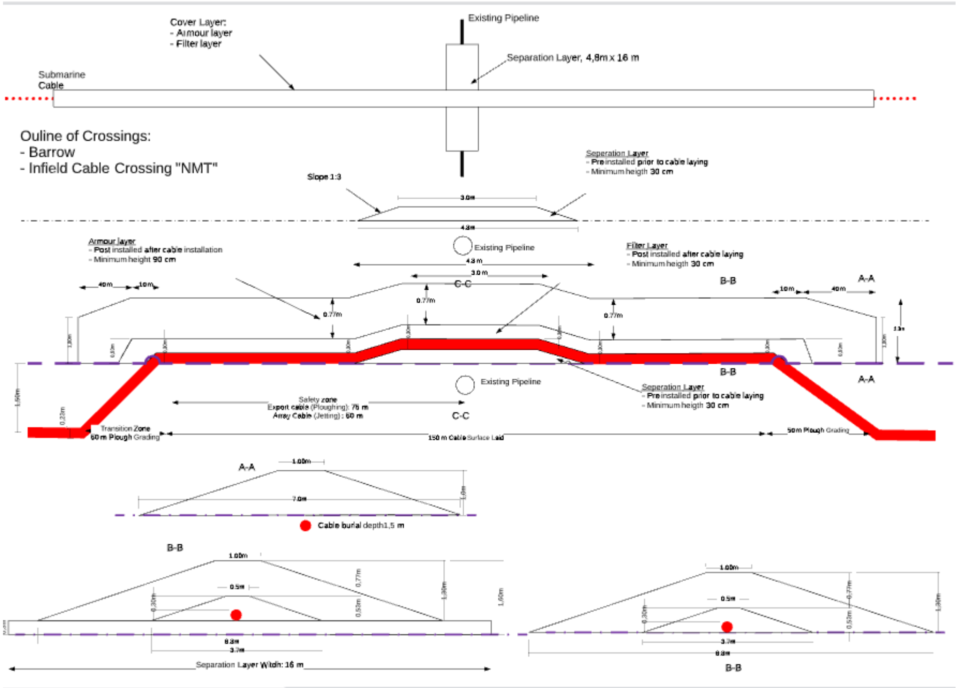
However, it is important to point out that it will be a temporary impact during the installation of the offshore cables and only for the near shore cable installation.

5.2.7 Crossing of cables and pipelines

In the case of submarine cables leading from the offshore wind farm to shore should cross existing cables or pipelines (crossings), the minimum vertical separation between them must be 0.3 meters. The distance is ensured either by pre-rock placement, installation of concrete mattresses over the existing cables or pipelines or using a pipe. The pipe needs to be buried to a depth of 1.5 m. Concrete mattresses are lowered to the seabed from a crane on a supply ship (Figure 5.4) and the final position of the concrete mattresses are checked with an ROV (remotely operated underwater vehicle). Further, a rock cover will secure the integrity of the crossing. Crossings are established at a 90° angle whenever possible. Prior to each crossing a written agreement with the cable or pipeline owner in question must be established. A special engineering crossing design will be aligned with crossed utility owner and implemented.

At crossings the landfall cables will be protected. Below a conceptual design of cable crossings is illustrated in Figure 5.3 below.

Figure 5.3: Conceptual design of cable crossing.



The protection consists of a 30 cm filter layer of sand and gravel and a 80 cm overlying protection of rocks. The crossings will approximately be 150 m long and 7 m wide. Including separation layer and protection layers each crossing will have a maximum height of up to 1,5 m.

Two existing cables are known and therefore a total of maximum 12 crossings are anticipated. The total volume of protection for crossings is 9.450 m³ material (rocks/ concrete mattresses).

Figure 5.4: Laying of concrete mattresses. [16]

5.2.8 Temporary deposit on the seabed of excavated material

In connection with installation of both inter array cables, export cables and cable crossings there may be a need for a temporary deposit offshore for the excavated material.

In connection with the installation of up to 6 offshore cables in parallel around 1,200 m^3 needs to be excavated and later backfilled for each cable which gives a total amount of 7,200 m^3. Depending on the work procedure for installation of the cables the need for temporary deposit will be from 1,200-7,200 m^3.

For each crossings of cables around 300 m^3 of excavated material is expected.

Excavation at the interface between the foundations and the cables will be around 810 m^3 depending on the foundation design.

Excavation of material due to unforeseen obstacles at the seabed can be up to 6,000 m^3.

5.2.9 Installation at landfall

The landing of the submarine cables will be carried out by horizontal directional drilling (HDD). By HDD a pilot hole is drilled underground which is enlarged by a reamer. Then a casing pipe is installed in the newly reamed path. Lastly the submarine cables are pulled through the casing pipe thus leaving the surface trenchless.

[16] Energinet 2019, Environmental Impact Assessment (miljøkonsekvensrapport) for Baltic Pipe in the North Sea.

HDD is further described in 02 section 2.2.7.

5.2.10 Installation time schedule

The total cable installation time estimated for both inter-array and export cables:

Survey:	15 days
Jetting trenches:	55 days
Jetting soft seabed:	95 days
Cleaning of trenches:	60 days
Pre-trenching (digging):	70 days
Backfilling:	55 days
In total:	350 days

6 Noise

6.1 Noise emissions from installation of piles

The underwater noise generated by pile driving during installation has been measured and assessed during construction of offshore wind farms in Denmark, Sweden and England among other countries. The noise level and emissions will depend, amongst other things, on the pile diameter, seabed conditions and pile driving equipment. An indicative source level of the pile driving operation would be in the range of SEL@1m = 200 – 225 dB re. 1 μPa^{2}s.

In accordance with Danish guidelines for offshore pile driving (Energistyrelsen, 2016), the installation of each pile must not cause permanent auditory injury (PTS) to marine mammals. This is measured by the total cumulated amount of sound energy emanating from a full pile installation, which must not exceed the given threshold value. If the pile installation activities are found to result in PTS, mitigation measures such as bubble curtains will be applied, so that the threshold value is no longer exceeded.

In relation to airborne noise emissions, the most extensive noise is also generated from installation of monopiles. A typical range that can be expected from piling at the source level, is normally within a range of LWA: 125-150 dB(A) LWA re 1pW, cf. airborne noise and vibrations, methods and assumptions[17].

6.2 Operational airborne noise emissions

There are two types of noise associated with operation of wind turbines: aerodynamic and mechanical noise. Aerodynamic noise is broadband in nature, relatively unobtrusive and is strongly influenced by incident conditions, wind speed and turbulence intensity. An operational Sound Power Level at the source is expected in the order of 105 dB(A) to 113dB(A), depending on the selected turbine type and the wind speed.

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 offshore wind farms.

[17] Rambøll april 2014, Metoder og forudsætninger for undersøgelse af luftbåren støj

Noise levels on land during the operation of the offshore wind farm are expected to be below allowed limits. The overall limits for operational noise on land according to the Danish legislation are:

- 44 dB(A) for outdoor areas in relation to neighbours (up to 15 m away) in the open land.
- 39 dB(A) for outdoor areas in residential areas and other noise sensitive areas.
  (Both measured at 8 m/s. If measured at 6 m/s, the limits are 2 dB lower)
- For low frequency noise (10 – 6,160 Hz) the limit is 20 dB(A) measured indoor in residential buildings.

Some mechanical noise may be generated from equipment on the OSS platform (transformers, diesel generators etc.) These noise contributions are not deemed significant for the overall noise emissions from the offshore wind farm.

7 Offshore Construction

In this chapter the offshore construction is described with regards to the construction programme, construction challenges in shallow waters, and access, lightings and emissions during the construction.

7.1 Offshore construction programme

The detailed plan for construction in the offshore wind farm area (i. e. foundations, WTG and inter-array cabling and export cabling) is not known at this time.

Prior to construction, several different offshore surveys will be conducted in 2023, i.e.:

- magnetometer investigations of unexploded ordnance (UXO) at possible WTG positions, at the proposed inter-array cable route, and at the proposed export cable route from the offshore wind farm to landfall,
- detailed geotechnical surveys based on the seabed investigations conducted during the summer of 2020,
- and possible additional geophysical and marine archaeological investigations based on the seabed investigations conducted during the summer of 2020.

Possible anomalies identified during the magnetometer surveys will be exposed and inspected by ROVs. Any revealed UXOs will removed, detonated, or disarmed by low order deflagration in close collaboration with the Danish Defense Ministry.

At each WTG locality and along the cable routes geotechnical investigations will be carried out.

An indicative time schedule for the offshore construction of Aflandshage Wind Farm is presented in Table 7.1, Table 7.2, and Table 7.3.

Table 7.1: Indicative time schedule for offshore construction of the 5.5-6.5 MW option. Time schedules for GBS and monopile foundations are shown in green and blue accordingly.

Time schedule Small WTG 5.5-6.5 MW (GBS and Monopile)	**2023**				**2024**				**2025**				**2026**			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Preliminary geotechnical surveys																
Installation of foundations for turbines																
Trenching and installation of export cables																
Installation of inter-array cables																
Installation of turbines																
Commissioning																

Table 7.2: Indicative time schedule for offshore construction of the 7.5-8.5 MW option. Time schedules for GBS and monopile foundations are shown in green and blue accordingly.

Time schedule Intermediate WTG 7.5-8.5 MW (GBS and Monopile)	**2023**				**2024**				**2025**				**2026**			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Preliminary geotechnical surveys																
Installation of foundations for turbines																
Trenching and installation of export cables																
Installation of inter-array cables																
Installation of turbines																
Commissioning																

Table 7.3: Indicative time schedule for offshore construction of the 9.5-11 MW option. Time schedules for GBS and monopile foundations are shown in green and blue accordingly.

Time schedule Large WTG 9.5-11 MW (GBS and Monopile)	**2023**				**2024**				**2025**				**2026**			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Preliminary geotechnical surveys																
Installation of foundations for turbines																
Trenching and installation of export cables																
Installation of inter-array cables																
Installation of turbines																
Commissioning																

The offshore construction work is very weather dependent. It is often possible to conduct the construction throughout the year, but the risk of adverse weather conditions preventing operations is higher during the winter months.

The most weather sensitive operation is expected to be the turbine installation. Øresund is relatively sheltered from larger waves, but wind speeds can still limit operations in poor weather conditions.

7.2 Access to site and safety zones

The construction of the proposed offshore wind farm is scheduled to take place throughout the year. Construction activity is expected for 24 hours per day 7 days a week until construction is complete.

A safety zone of 500 m is expected to be established around the main construction sites in order to protect the project, personnel, and for the safety of third parties during the construction and commissioning phases of the offshore wind farm. The safety zone may include the entire construction area, or a rolling safety zone may be selected. The exact safety zone will be agreed with the DMA prior to construction.

It is intended that third parties will be excluded from any safety zone during the construction period, and that the zone(s) will be marked in accordance with the requirements from the DMA, section 7.3.

To optimise the construction program, it is likely that installation of wind turbines, foundations and cables will be undertaken on the site at the same time, although not necessarily within the same part of the site. Therefore, it is likely that approximately 10-15 vessels (including support vessels) may be on site at any time during the construction phase.

7.3 Lighting and markings during construction

The status of the construction area including markings and lighting 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 the DMA and the DTA.

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 as construction progresses. The same safety procedures will apply for laying of the export cables.

During construction the complete construction area shall be marked with yellow lighted buoys with a reach of at least 2 nautical miles. Details on the requirements for the positions and number of buoys shall be agreed with the DMA. If cranes of 100-150 m height will be used during construction, these shall be marked with fixed red light of low intensity (10 candelas as a minimum).

7.4 Emissions and discharges

During construction and operation (and decommissioning) some emissions to the atmosphere will be emitted from the vessels working on surveys, investigations, construction, operation and decommissioning phases.

Differences in vessel traffic and emission due to various cable laying methods are negligible compared to the total shipping traffic and emission when building a offshore wind farm.

In addition, there is a minor risk of accidental discharges or spill from the turbines or marine vessels associated with construction and decommissioning. No oil must be discharged intentionally in Danish territorial waters according to the Danish Regulation no. 539 of 22/05/2017 on discharge of oil from marine vessels[18].

There are no anticipated solid discharges into the marine environment during the construction phase. All waste generated during construction will be collected and disposed of by licensed waste management contractors to licensed waste management facilities onshore. It will be required that the vessels working during construction, operation and decommissioning must comply with Act no. 1165 of 25/11/2019 on protection of the marine environment (havmiljøloven)[19].

[18] BEK nr. 539 af 22/05/2017 om udtømning af olie fra skibe
[19] LBK nr. 1165 af 25/11/2019. Bekendtgørelse af lov om beskyttelse af havmiljøet (havmiljøloven).

8 Operation and maintenance

Operation and maintenance of the offshore wind farm will continue 24 hours per day, 365 days per year, and access to site may be required at any time. Planned operation and maintenance activities will be between 06:00 and 19:00 while jack-up operations can be from 00:00 to 24:00.

8.1 Access to site and safety zones during service life

Safety zones can be applied for the offshore wind farm area or parts hereof. The specific safety zones will be determined by the DMA.

A 200 m safety zone around all cables will be expected. The safety zone of 200 m on either side of the cables will normally include restriction for anchoring that may be intrusive into the seabed. The project needs to comply with Regulation no. 939 of 27/11/1992 on protection of sea cables and submarine pipes[20] specifying these protection zones and agree with the DMA on the extent of potential safety zones.

For all turbines it is not expected to include a prohibited entry zone around the foundations for non-project vessels. For the actual project the decisions on prohibited entry zones will be made in coordination with the DMA.

8.2 Service and maintenance

The offshore wind farm will be serviced and maintained throughout the life of the offshore wind farm from a local port in the vicinity of the offshore wind farm. The port to be used during maintenance has not yet been identified, but four ports have been proposed by HOFOR: the rescue port near Copenhagen Airport, Dragør port, Prøvesten port and Klagshamn port. A CTV (crew transfer vessel) will be stationed at the designated port for the offshore wind farm. The CTV will ship crew and parts for maintenance, to the offshore wind farm. Following the commissioning period of the offshore wind farm, it is expected that the scheduled inspection and servicing interval for the turbines will be approximately every twelve months. Ten visits per turbine per year is expected including scheduled and unscheduled visits. A total of around 250-350 CTV sailings per year to Aflandshage Wind Farm is to be expected.

Figure 8.1: Maintenance of a wind turbine by crew transported in a crew transfer vessel.

[20] BEK nr. 939 af 27/11/1992. Bekendtgørelse om beskyttelse af søkabler og undersøiske rørledninger (kabelbekendtgørelsen).

Maintenance schedules of the offshore wind farm depend on the turbine type installed, but is normally separated into two different categories:

1. Scheduled inspection/maintenance
2. Un-scheduled maintenance

8.2.1 Scheduled inspection/maintenance

Scheduled inspection/maintenance primarily involves inspection and replacement of wear parts, check of lubrication and other fluids and filters. A scheduled inspection of each turbine lasting approximately three days is likely to take place once a year. Scheduled maintenance will be performed using service vessels operated from the local port.

Inspections of support structures and subsea cables will be performed on a regular basis as well as ad-hoc visits for surveillance purposes, e.g., following a storm.

Periodic service and replacements will be carried out in accordance with the turbine manufacturer's recommendations. These activities will be planned for execution in the periods of the year with the best access conditions, preferably in summer. The periodic service and replacements will be carried out according to the supplier's specifications. The work 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.

8.2.2 Unscheduled maintenance

Unscheduled maintenance involves the correction of any sudden defects. The scope of such maintenance may range from correcting defects or replacing minor components to repairing or replacing failed main components, such as generator, gearbox, transformer, main bearings, rotor blade.

The repair or replacement of minor components can be completed using the staff and vessels involved in the regular scheduled maintenance, but if the correction of the defect involves the removal/replacement of one of the main components of the WTG, it may require assistance from vessels like those involved in the construction of the offshore wind farm. Replacement of main components will be a 24 hour operation.

8.3 Consumables

The operation and maintenance activities involves regular replacement of worn parts, lubrication and refilling of liquids. The relevant type and quantities are very dependent on the turbine type and size selected.

The replacement of worn parts is part of the regular maintenance routine, and even the replacement of one or more main components is likely to be required during the lifetime of the offshore wind farm.

There are no anticipated direct discharges to the atmosphere or anticipated solid discharges into the marine environment during normal operation of the turbine array. All waste generated during operation, e.g., associated with maintenance, will be collected and disposed of by licensed waste management contractors to licensed waste management facilities onshore. Table 8.1 gives an estimate of the amount of various consumables and for a typical turbine.

Table 8.1: Estimate of O&M consumables pr. turbine.

Consumable	Type	Quantity	Change frequency, months	Quantity/ year
Yaw gear oil	Semi-synthetic	50-100 l	60-240	6 l
Gear oil	Full synthetic	1,100-2,000 l	96	300 l
Gear oil filter	Paper/ cartridge	3 nos.	12	3 nos.
Brake lining	Sinter metal	1-2 nos.	12	1-2 nos.
Hydraulic oil	Full synthetic	250-1,200 l	120	
Filters on hydraulic oil system	Paper/ cartridge	1-3 nos.	12-60	<1 no.
Coolants – water	50 % glucol	100-300 l	120	50 l
Coolants – silicone oil	Silicone oil	1,800 l	-	-
Lubricant	Oil or grease	-	-	10 l
Generator slip rings/brushes	80 % Cu	12 nos.	60	3 nos.

9 Decommissioning

The life span of the offshore wind farm is estimated at 35 years with a license for 30 years of operation with a possible extension of 5 years operation. It is expected that two years in advance of the expiry of the production time the developer shall submit a decommissioning plan. The method for decommissioning will follow best practice and the legislation at that time.

It is unknown at this stage how the offshore wind farm may be decommissioned; this will have to be agreed with the competent authorities before the work is initiated. It is expected that an EIA statement (miljøkonsekvensvurdering) will be required for the decommissioning of the offshore wind farm.

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.

9.1 Extent of decommissioning

The objectives of the decommissioning process are to minimise both the short- and long-term effects on the environment whilst making the sea safe for others to navigate.

The decommissioning process includes, in principle, total removal of the offshore wind farm and restoration of affected seabed and coastal areas, as necessary.

The decommissioning process includes, in principle, total removal of the offshore wind farm and restoration of affected seabed and coastal areas, as necessary.

9.2 Decommissioning an offshore wind farm

9.2.1 Decommissioning of wind turbines

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

9.2.2 Decommissioning of buried cables

Recovery of buried cables will essentially be the reverse of a cable laying operation, with removal of protecting concrete mattresses and rock cover, followed by removal of cables by working the cable handling equipment in reverse gear and the cable either being coiled into tanks on the vessel or guillotined into sections approximately 1.5 m long immediately as it is recovered. These short sections of cables would then be stored in skips or open containers on board the vessel for later recycling of main components.

Uncovering the cables will cause a disturbance of the seabed and caused sediments to be suspended in the water and dispersed.

9.2.3 Decommissioning of foundations

Foundations may be decommissioned through partial of complete removal.

For monopiles the most likely scenario is that that the foundations will be removed to at or just below the level of the natural seabed.

The removal of GBS foundations will involve the removal of the ballast before the concrete structures can be lifted from the seabed. It may be required to inject water at high pressure under the foundations to loosen these from the seabed.

Alternatively, the concrete structures may be demolished in situ and removed in pieces.

Complete removal of foundation structures is an assumption for the environmental assessment for Aflandshage OWF. However, during the operation of the wind farm a natural reef community of flora and fauna most likely will evolved on and around the structures. In connection with decommissioning it may therefore be considered to keep (some of) the foundation structures in order to conserve such biological communities. The issue will have to be addressed and settled by the OWF owner and the competent environmental authority at the time of planning the decommissioning.

9.2.4 Decommissioning of scour protection

As for the foundation structures, a natural reef community will most likely evolve on and around the scour protection. Whereas removal of scour protection is the assumption for the environmental assessment for Aflandshage OWF, it is foreseen that it may be considered – in the decommissioning plan – to conserve the evolved communities by leaving the scour protection.

Furthermore, it will not be practically possible to remove all scour protection materials as major parts of it must be expected to have sunk into the seabed. Also, it is expected that the scour protection will function as a natural stony reef. The removal of this stony reef is expected to be more damaging to the environment in the area than if left in situ. It is therefore considered most likely that the regulators at the time of decommissioning will accept or require the scour protection to be left *in situ*.

9.3 Disposal or reuse of components

It is likely that legislation and custom will dictate the practices adopted for the decommissioning of the offshore wind farm. The decommissioned materials might have the following disposal or recycling methods:

- All steel, cast iron, copper and other metal components scrapped and recycled.
- The turbine blades (GRP and carbon fibre) as well as GRP grating to be disposed of in accordance with the relevant regulations in force at the time of decommissioning.
- Reuse of concrete from foundations. Crushed concrete is typically used as fill material for civil engineering projects but does represent a low monetary value.
- All heavy metals and toxic components (likely to be small in total) disposed of in accordance with relevant procedures and regulations.

As of today, there no suitable recycling potential for GRP exists. This is a focus area for the Danish and the international wind farm industry, and it is expected that relevant methods of dismantling and recycling of GRP containing components may be available on the time where the wind farm will have to be decommissioned.

PART 2: LANDFALL / ILANDFØRING

1 Introduktion

I nærværende del 2 beskrives ilandføring af kabler fra Aflandshage Vindmøllepark hvoraf afsnittene indeholder metodebeskrivelser, oversigt over anvendt materiel og overordnet anlægstidsplan (entreprenørtidsplan).

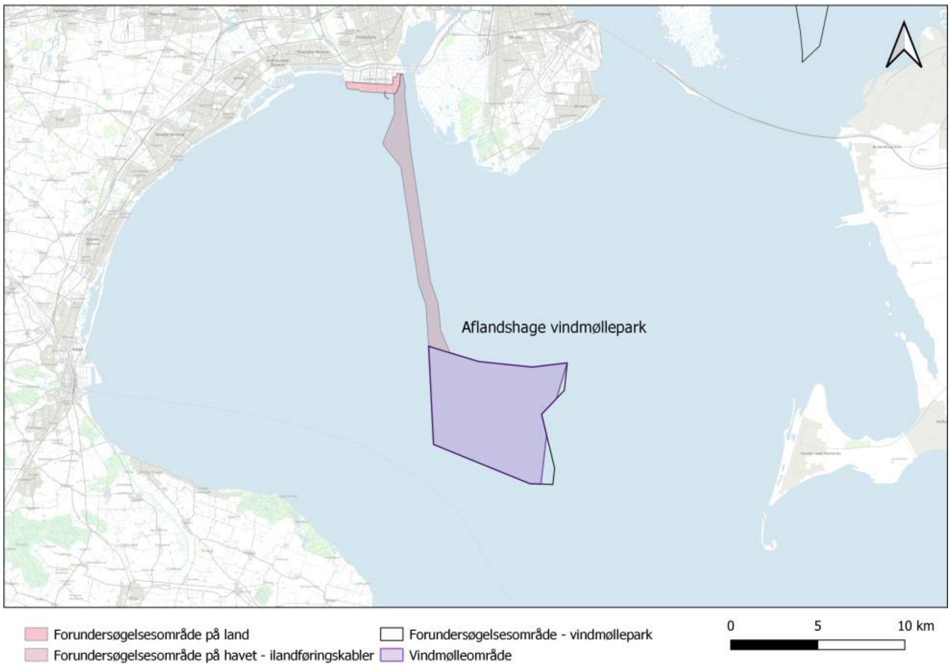
Ilandføring af kabler dækker over kabellægning på delstrækningen mellem offshore og onshore kabellægning. Ilandføring udføres derfor delvist i vand og delvist på land og den anvendte anlægsmetode skal tilpasses overgangen mellem entre-priserne.

Ilandføring af kabler udføres ofte med metoder og udstyr, der i udgangspunktet afviger fra metoderne anvendt offshore og onshore, hvorfor ilandføringsarbejdet beskrives særskilt i nærværende del 2.

2 Projektlokalitet

Beskrivelsen omfatter ilandføring af kabler fra Aflandshage Vindmøllepark til Avedøreværket. Af Figur 2.1 ses vindmølleparkens placering samt den tilhørende kabelkorridor frem til ilandføringsområdet.

Figur 2.1: Oversigt over forundersøgelsesområdet for vindmølleparken og kabelkorridoren til ilandføringskabler.



Af Figur 2.2 fremgår det forventede ilandføringsområde ved Avedøreværket.

Figur 2.2: Ilandføringsområdet for kabler fra Aflandshage Vindmøllepark til Avedøreværket markeret med rød. Det nøjagtige ilandføringspunkt er på nuværende tidspunkt ikke endeligt fastlagt. På figuren ses ligeledes en omtrentlig placering af transformerstationen på land (pink markering), hvor kablerne skal føres til efter ilandføring.

Der forventes ilandført mellem 3 og 6 kabler hvis transformerstationen placeres på land og 1 kabel hvis transformerstationen placeres på havet. Kablerne ledes via onshore kabelføring videre til transformerstationen på land eller til nettilslutningspunktet hvis transformerstationen placeres på havet. Det endelige antal af kabler er endnu ikke fastlagt og afhænger af den valgte vindmøllestørrelse.

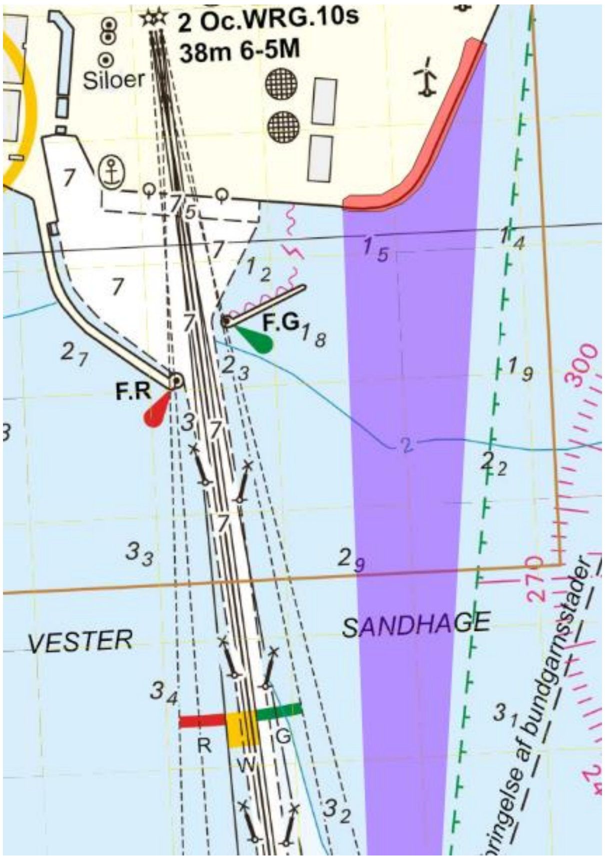
Grænsefladen mellem ilandføringsområdet og onshore-området vil i nærværende beskrivelse være defineret som overgangen fra søkabler til landkabler i et transition joint. Placeringen af transition joints afhænger af ilandføringspunktet, som vil ligge inden for det røde område, der er vist i Figur 2.2.

Ilandføringen etableres i en gravet rende eller gennem et foringsrør anlagt med en boret metode. Foringsrørets længde afhænger af de geologiske forhold ved ilandføringsstedet, som afdækkes med detaljerede geofysiske undersøgelser.

2.1 Dybdeforhold nær kysten

Dybdeforholdene i denne del af forundersøgelsesområdet influerer den tilgængelige anlægsmetode. På Aflandshage er vanddybden ud for det markerede ilandføringsområde relativt lav i en større afstand fra kystlinjen. Nær kysten er dybden 1,0-1,5 meter og i overgangen mellem offshore og ilandføringsområdet er dybden mellem 3,0-3,5 meter, svarende til ca. 750 meter ud i bugten.

Figur 2.3: Udklip af søkort 134 fra området ved ilandføringsområdet (markeret med rød) ved Avedøre Holme og den forventede korridor for foringsrørene (markeret med lilla). © Geodatastyrelsen – 320-0003



I det følgende vil de mere lokalitetsspecifikke forhold blive beskrevet samt hvilke potentielle metoder kablerne kan ilandføres ved.

3 Etableringsmetode for ilandføring af kabler

Af hensyn til tidsplanen og for at undgå grænsefladekonflikter mellem offshore og onshore entreprenørerne skal ilandføringen være forberedt, når disse arbejder igangsættes. Ilandføring af kablerne ved Avedøreværket forventes derfor at ske ved itrækning gennem et foringsrør/trækrør.

Foringsrørene forventes etableret fra indvendig side af diget, der afgrænser det tidligere askedepot fra adgangsvejen, til et p.t. udefineret punkt i Køge Bugt.

Der er om end mulighed for, at en del af kablerne indenfor korridoren etableres uden anvendelse af foringsrør. Dette gælder for den strækning af kablerne beliggende mellem foringsrørenes afslutning og grænsefladen mellem ilandføringsområde og offshore-området.

Grænsen mellem ilandføringsområde og offshore-området defineres af de tilgængelige fartøjers dybgang og burial assessment (lægningsdybder/tilsanding af render). Afstanden fra ilandføringsområdet langs kysten og frem til overgangen mellem offshore- og ilandføringsentreprisen forventes imidlertid at være placeret ca. 750 meter fra kysten.

Ilandføring af kablerne vurderes indledningsvis at kunne udføres ved én overordnet anlægsmetode, der forudsætter et forberedt foringsrør/trækrør. Foringsrørenes dimension er imidlertid forudsat til 800 mm i diameter og forventes udført ved en af nedennævnte metoder:

- Foringsrør etableret ved gravning
- Foringsrør etableret ved opgravningsfri metode

Flere parametre gør sig gældende i forbindelse med vurderingen af de respektive ilandføringsmetoder, herunder eksisterende bathymetriske forhold, pladsforhold, jordbundsforhold samt tilstedeværelsen af eksisterende konstruktioner og anlæg, beliggende mellem kystlinjen og foringsrørets afslutning på land. Overordnet set vil begge metoder kræve følgende:

1. Etablering af adgangsveje, herunder eventuel forstærkning eller stabilisering
2. Afrømning af arealet og forberedelse af adgangsveje samt anstilling af arbejdsplads
3. Etablering af foringsrør ved enten gravning eller opgravningsfrit
4. Demobilisering af arbejdsplads for udførelse af foringsrør samt forberedende arbejder for anstilling af arbejdsplads til itrækning af kablerne.
5. Retablering af arealet i henhold til aftaler med dels lodsejer og dels myndighed samt fjernelse af midlertidige adgangsveje

I de følgende afsnit vil adgangsforhold, forslag til etableringsmetoder samt arealbehov blive belyst.

3.1 Adgangsforhold

Adgang til arbejdsområdet forventes at ske via offentlige og private veje. Adgangsvejene inden for Avedøreværket udgøres af 7 meter brede asfalterede veje og 3,5 meter brede asfalterede og grusbelagte veje. Fordelingen af vejtyper fremgår af Figur 3.1.

Figur 3.1: Adgangsvej til ilandføringsområdet. Blå markering angiver 7 m bred asfalteret vej, cyan markering angiver 3,5 m bred asfalteret vej og grøn markering angiver 3,5 m bred grusvej.

Som det ligeledes fremgår eksisterer der adgangsveje helt frem til det foreslåede ilandføringsområde, om end det er vurderet at nogle vejstrækninger behøver en midlertidig sideudvidelse for, at sikre tilstrækkelig bredde til at nødvendigt maskinel kan transporteres frem og tilbage fra arbejdsområdet.

Figur 3.2: Adgangsveje indenfor Avedøreværket (grusvej langs kysten t.v. og asfalteret vej t.h.).

Adgangsveje for såvel arbejdspladsen kan behøve supplerende stabilisering eller forstærkning ved f.eks. at befæste arealet med køreplader eller udlægning af stabilgrus separeret fra eksisterende terræn med fiberdug. Omfanget af forstærkning og arealbehovet afhænger dog af udførselsmetoden, hvoraf forslag til udførselsmetoder vil blive beskrevet i det følgende.

3.2 Arbejdsprocedure

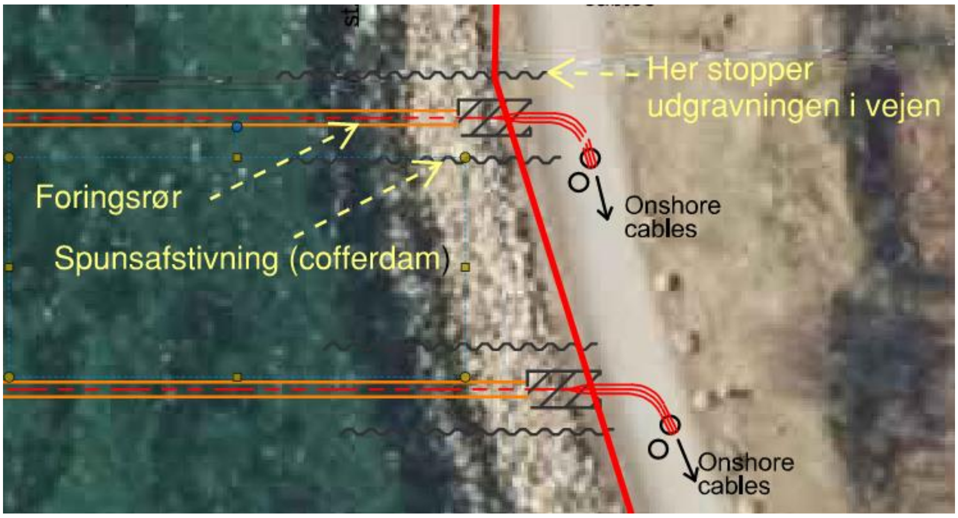
3.2.1 Procedure for etablering af foringsrør ved gravning

3.2.1.1 *Arbejdsprocedure*

Installation af foringsrør/trækrør kan potentielt etableres enten via spuling, gravning eller en kombination heraf. Idet der ikke på nuværende tidspunkt foreligger oplysninger om jordbundsforholdene fra geofysiske og geotekniske forundersøgelser, er den endelige etableringsmetode ikke fastlagt og alle metoder er fortsat mulige.

For at få kablerne ført gennem ilandføringspunktet skal der graves gennem stensætningen/diget. Materialet fra diget vil blive mellemdeponeret på stedet for senere genindbygning. For at sikre at der ikke sker materialeudvaskning/udsivning etableres der en dobbeltafstivet spuns, som når op over eksisterende terræn, jf. Figur 3.3.

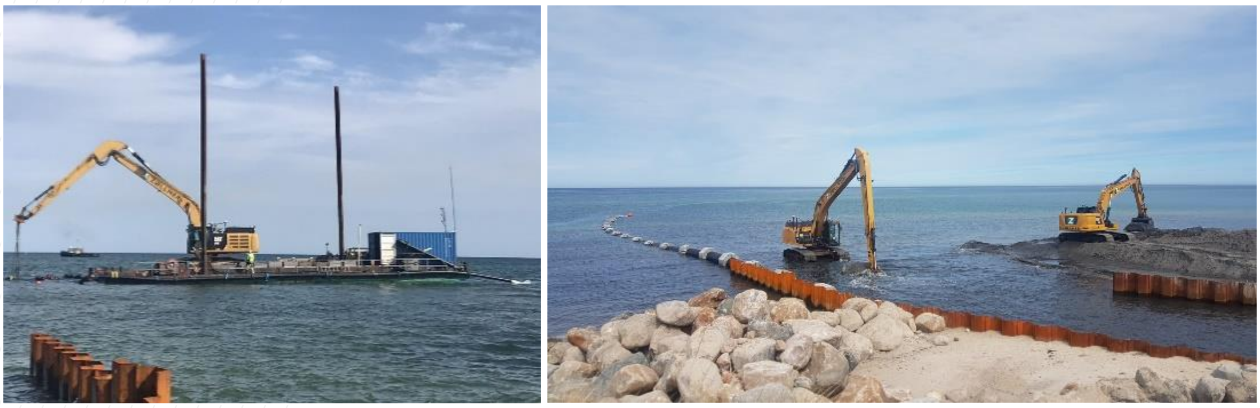
Figur 3.3: Afstivning og gravning gennem diget



Som det fremgår af Figur 3.3 vil spunsen stoppe inden vejmidten. Idet det forventes at jorden kan stå med anlæg 1:1, vil udgravningen maksimalt nå ud til vejens midte. Der vil dermed ikke være fare for, at der skabes kontakt mellem havvandet og askedepotet, idet der ikke forekommer askedeponi i vejen. Det vil blive sikret via bortpumpning at ledningsgraven vil blive tørholdt således, der ikke strømmer vand fra Køge bugt ind i udgravningen og hvorfor der ikke vil blive skabt kontakt til askedepotet.

Længere ude på vandsiden kan det blive nødvendigt at føre afstivningen videre ud for at sikre foringsrørene mod træk og indskylning af materialer i brændingen, hvorfor der etableres landfæste i form af en nedvibreret spuns (kofferdam) eller anden afstivning, hvor foringsrørene fikseres, inden de flådes ud på søterritoriet.

Figur 3.4: Eksempel på offshore og kystnært arbejdsprocedure for etablering af foringsrør (COWI, Skagen, maj 2020)



Foringsrørene nedsænkes i udgravningen indenfor kofferdammen samt i den forberedte ledningsgrav offshore. Til sikring mod opdrift på foringsrøret monteres jævnt fordelte ballastklodser i beton eller tilsvarende foranstaltning. For at undgå potentielt skadelige sætninger udføres ballasteringen så de ballasterede foringsrør belaster den underliggende havbund mindst mulig.

Foringsrørene forventes udført i enten polyethylen (PE) eller stål og samlet ved svejsning, hvoraf oplæg af svejste foringsrør ventes udlagt langs grusvejen parallelt med kysten, se Figur 3.5. Rørene forventes svejst på land i delsektioner, der efterfølgende vha. bugserfartøjer flådet ud på vand. Et område langs kysten med en bredde på ca. 4-6 m samt en længde svarende til de sammensvejste sektioner forventes anvendt som arbejdsareal.

Den foreslående placering af oplagrede og svejste foringsrør fremgår af Figur 3.5.

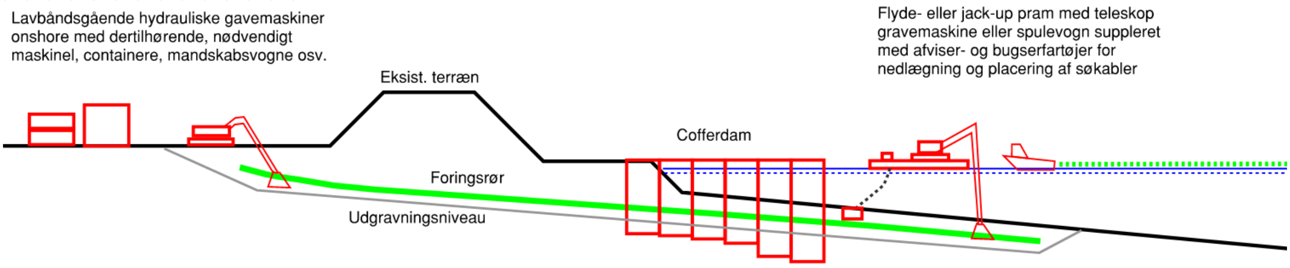
Figur 3.5: Illustration af svejst og oplagring af rør (COWI, Skagen, maj 2020) samt forslag til placering langs grusvejen samt forslag til placering af svejste rør (pink markering) og ydre periferi for afgrænsning af arbejdsareal (blå markering)

Foringsrøret, hvorigennem kablerne slutteligt skal trækkes, kan udlægges på havbunden og løbende spules ned i ønskede dybde med spulevogn (Remote Operated Vehicle, ROV). Alternativt forberedes en gravet rende med hydrauliske gravemaskiner placeret på flydepram, entreprenørskib eller jack-up rig. Ved kystnære arbejder på lavere vanddybde forventes rørene, hvis jordbundsforholdene tillader det, at blive udført med larvebåndsgående gravemaskiner kørende på selve havbunden.

Grundet lave vanddybder nær kysten, vil mulighederne for brug af offshore maskinel i form af pram, entreprenørskib, jack-up pram mv. sandsynligvis være forholdsvis begrænsede omend ikke nødvendigvis umulige.

En konceptuel illustration af arbejdspladsen og arbejdsproceduren for arbejderne on- og offshore fremgår af Figur 3.6.

Figur 3.6: Konceptuel illustration af foringsrør udført ved spuling/gravning med gravemaskiner, jack-up rig eller flydepram.



Idet vanddybden for hele det planlagte forløb ikke overstiger 1,5-2,5 meter, kan det desuden muliggøres at opgravet havbudsmateriale indbygges i en midlertidig undersøisk dæmning/plateau parallelt med ledningsgraven, hvorpå larvebåndsgående gravemaskiner vil kunne køre ud til større vanddybder. Dermed bliver anvendelse af flydepram sandsynligvis ikke aktuelt.

Det nøjagtige omfang af gravearbejde udført med gravemaskine på larvebånd afhænger af jordbundsforholdene samt dybdeforholdene. Hvis udgravning med gravemaskine viser sig uhensigtsmæssig, kan det blive nødvendigt at udføre nedspuling – også for mere kystnære arbejder. Det ventes at gravemaskinen kun kan køre et stykke ud, hvorfor den resterende del af tracéet må forventes nedspulet eller gravet med hydrauliske gravemaskiner placeret på en flyde- eller jack-up pram.

Den opgravede jord indbygges i udgangspunktet direkte i ledningsgraven og eventuelt overskudsjord udlægges på bunden parallelt med selve udgravningen. Således forbliver det opgravede sediment i sit naturlige miljø hvilket med tiden, grundet den mekaniske påvirkning fra vind og vejr, udjævnes således det oprindelige havbundsniveau opnås.

Foringsrørene nedsænkes på havbunden/i ledningsgraven ved påfyldning af havvand hvormed ledningen, i takt med påfyldningen, sænkes til den ønskede placering. Slutteligt nedspules ledningerne med ROV el. lign. eller der tilbagefyldes og tildækkes med gravemaskine.

Det forventes, at selve arbejdet med etablering af foringsrørene på vand vil kunne udføres på ca. 6-8 måneder (afhængig af antallet). Anstilling til søs kan forventes svarende til den i Figur 3.7 illustrerede.

Figur 3.7: Eksempel på offshore og kystnært arbejdsprocedure for etablering af foringsrør. (COWI, Mariagerfjord 2017)

3.2.1.2 *Stormflodssikring*

Gennembrydningen af det eksisterende stormflodsdige vil kun blive planlagt i perioder med acceptable vejrvindue, hvor risikoen for oversvømmelse er ikke eksisterende. Som en supplerende sikkerhed vil entreprenøren blive afkrævet at have planlagt og være mobiliseret for afværgeforanstaltninger mod indtrængende vand og en prompte retablering af stormflodsdiget såfremt et uforudset stormvejr eller øget vandstand forekommer.

3.2.1.3 *Arbejdsplads*

Arbejdspladsens størrelse afhænger af antallet af foringsrør (op til 6 stk.), rørdimensionen mv. men det vurderes at et arbejdspladsareal på ca. 750-1.000 m² onshore vil være tilstrækkeligt for udførelse og nedlægning af foringsrør ved gravning.

3.2.2 Procedure for etablering af foringsrør opgravningsfrit

3.2.2.1 *Arbejdsprocedure*

Styret underboring, HDD (Horizontal Directional Drilling) er en betegnelse for en opgravningsfri metode, der kan anvendes til etablering af rør, kabler mv. Der anvendes en borerig, der placeres ved boringens startpunkt (entry-point), og denne borer direkte til boringens slutpunkt (exit-point) uden at forstyrre terrænoverfladen. Når der er opnået en tilstrækkelig dimension af borehullet, itrækkes det pågældende rør gennem det forberedte borehul.

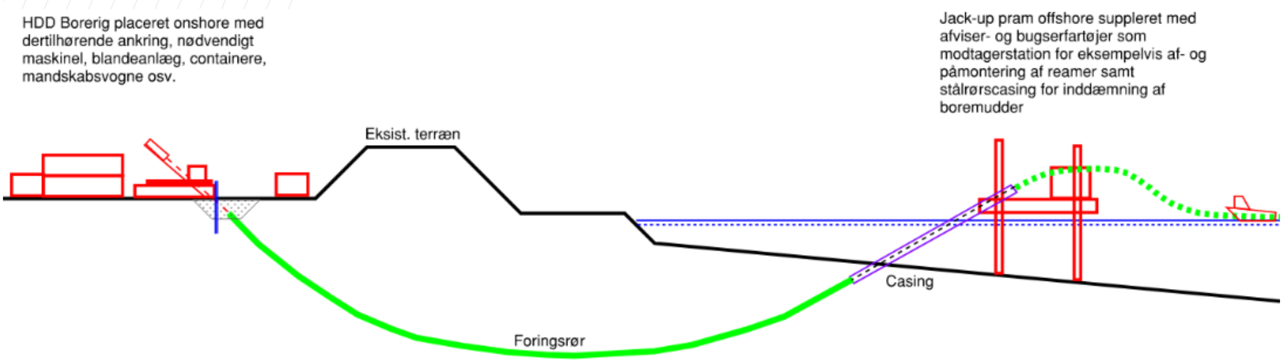
Den styrede underboring indledes med en pilotboring, hvor der drives et roterende borerør med et styrbart borehoved frem. Borehovedet, der anvendes ved pilotboringen, har en relativt lille størrelse, for at muliggøre fremdrift i den uforstyrrede jord. Det betyder, at borehullet skal udvides, for at itrækning af røret/kablet kan muliggøres. Udvidelsen foregår med reamer, der monteres, når pilotrøret entrerer overfladen ved exit-pointet. Et eksempel på en reamer fremgår af Figur 3.8.

Figur 3.8: Eksempel på reamer for udvidelse af borehullet fra pilotboringen.

Reameren trækkes tilbage til entry-punktet og borehullet er således udvidet ift. pilotboringen. Borehullet forventes opreamet af 3-4 gange ved anvendelse af stadig større reamere, indtil en passende diameter ift. den ønskede rørdimension er nået. Når der er opnået en passende dimension af borehullet, itrækkes foringsrøret fra slutpunktet til startpunktet.

På denne projektlokalitet foretages boringen fra land og bores ud i Køge Bugt. Ved boringens exit-punkt placeres en flydepram/jack up-pram eller et lignende fartøj, der kan gå ind på lav vanddybde. Prammen anvendes til af- og påmontering af borehoved og reamere. Af Figur 3.9 fremgår en konceptuel illustration af en styret underboring fra land til vand.

Figur 3.9: Konceptuel illustration af foringsrør udført ved styret underboring (HDD) fra land og ud til modtagerstation offshore (jack-up rig eller flydepram).



For at opretholde et åbent borehul, køle og smøre borehovedet samt transportere cuttings (udboret materiale) ud af borehullet mm., anvendes boremudder. Boremudder består i hovedtræk af vand, bentonit og forskellige additiver. Det forventes at vand til boremudder tilkøres med vandvogne og sammenblandes i en mixing unit. Alternativt anvendes havvand fra projektlokaliteten.

I Tabel 3.1 gives eksempler på additiver som anvendes af entreprenører i boremudderet.

Tabel 3.1: Typer af additiver tilsat boremudder

Produkttype	Produkteksempel	Anvendelse
Viskositetsforøgende tilsætningsstof	Tunnel-Gel-Plus	– Øger viskositet, så boremudderet kan bære materiale ud langs røret.

Produkttype	Produkteksempel	Anvendelse
		– Opbygger filterkagen, der nedsætter udsivningen af væske til jorden, og stabiliserer borehullet.
Soda ash	-	Justerer pH-værdi så tilsætninger kan opblandes og virker effektivt
Polymer	PAC-L	– Hæmmer leret – Styrker filterkagen, så der ikke siver væske ud i jorden
Boremudder	Premium Gel	Boremudder
Smøremiddel til gennemtrækning af kablet	Cable Jetting Lube	Smøremiddel til gennemtrækning af kabler

Det forventede forbrug af boremudder vurderes på nuværende tidspunkt at udgøre 3-5 gange volumen af det opreamede borehul svarende til 1,3 gange foringsrørets udvendige diameter. Det forventede boremudderforbrug vil derfor være i omegnen af 10.000 m³ og 20.000 m³ for hhv. 3 og 6 kabler. Det forudsættes at produkterne kan blive godkendt af de lokale myndigheder.

Det forventes, at der anvendes ikke miljøbelastende additiver i form af biologisk nedbrydelige polymerer. Derudover forventes det, at der skal etableres en midlertidig foranstaltning mod udsivende boremudder fra slutpunktet. Foranstaltningen kan udgøres af eksempelvis et stålrørs-casing eller en kofferdam, der udføres fra prammen og ned i havbunden. På denne måde inddæmmes boringens slutpunkt og mængden af boremudder der strømmer ud i havet minimeres.

De geotekniske forhold på projektlokaliteten er for nuværende ukendte, men har betydning for hvorvidt en styret underboring er plausibel. Dette gælder bl.a. ved pilotboringen, hvor borehovedet tilpasses de jordbundsforhold, der opereres i. Derudover tilpasses forbruget af boremudder til de geotekniske forhold, for at opretholde det operationelle boremuddertryk og minimere risikoen for borehulskollaps.

Boringens nødvendige dybde styres af flere parametre, herunder jordlagets karakteristika, styrkeparametre, risiko for blow-out mv. og kan ikke endeligt fastlægges på nuværende projektstadie, eftersom der ikke foreligger geotekniske og geofysiske undersøgelser. Det vurderes, at boringsdybden skal være så tilstrækkelig stor, at risikoen for eksempelvis beskadigelse af foringsrøret ved ankerkast er minimal.

Rørene forventes svejst på land og efterfølgende flådet ud på vand vha. bugserfartøjer. Et område langs kysten med en bredde af ca. 4-6 m samt en længde svarende til de sammensvejste sektioner forventes anvendt som arbejdsareal til sammensvejsning.

3.2.2.2 Arbejdsplads

Arbejdspladsens størrelse afhænger af antallet af foringsrør, dimensionen, længden på boringen, myndighedskrav ift. boremudder osv., idet ovenstående parametre afgør boreriggens størrelse samt eventuelt behov for recirkulations anlæg mv. om end det vurderes, at et arbejdspladsareal af omtrentligt 2.000-2.500 m² er tilstrækkeligt.

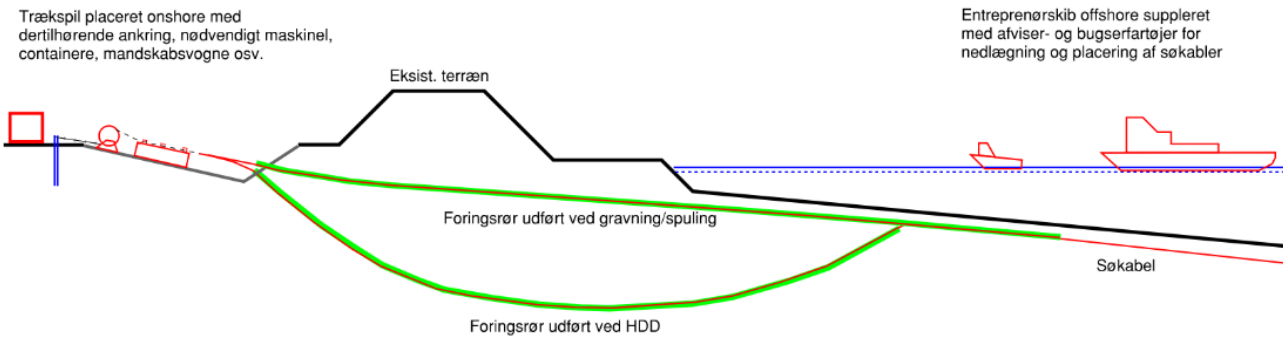
3.3 Installation og itrækning af eksportkabler

Efter endt etablering af foringsrørene skal kablerne installeres. Installation, herunder itrækning af kabler, forventes udført ved hjælp af fastmonterede sjækler på kablerne samt forankrede elektriske trækspil. Den nødvendige forankring afhænger af kabelstrækkets længde, dimension, jordbundsforhold mv. og kan bestå af f.eks. nedrammede spunsjern, nedborede pæle eller et støbt anker under terræn.

Ved montering og hæftning af trækspil, sjækler osv. til kablerne, skal der fra entreprenørskibet udsendes dykkere for inspektion, kontrol og koordinering af arbejderne under vand.

Af Figur 3.10 fremgår en konceptuel illustration af hvilket maskinel der benyttes i forbindelse med installation og kan forventes for denne arbejdsgang.

Figur 3.10: Konceptuel illustration for itrækning af kabler med bugserfartøjer, trækspil, anker mv. gennem foringsrør forberedt ved både styret underboring (HDD) og gravning/spuling.



Afhængig af størrelsen og antallet af kabler vurderes det, at det nødvendige arbejdsareal for anstilling af anker, trækspil, generatorer, kontrolstation mv. kan foretages indenfor et areal onshore af ca. 1.000-1.500 m². Dette arbejdsareal vil uanset foringsrørenes udførselsmetode være gældende og vil ligesom alle andre operationer i dette projekt, være afhængig af parametre som dimension af foringsrør, antal osv.

3.3.1 Arealbehov onshore

Arbejdspladsens størrelse afhænger som beskrevet af flere parametre og vil behøve en revision i takt med at projektgrundlaget udbygges.

Arealbehovet er estimeret ud fra et yderst sparsomt grundlag og skal derfor læses med en del usikkerhed. Det skal bemærkes, at arealer til oplag af svejste foringsrør ikke er inkluderet i arealerne anført i Tabel 3.2.

Tabel 3.2: Estimeret arealbehov for onshore arbejdsplads.

Arbejdsformål	Arealbehov onshore [m²]
Udførelse af foringsrør ved gravning	750-1.000
Udførelse af foringsrør ved styret boring	2.000-2.500
Itrækning af eksportkabler	1.000-1.5000

De anførte arealbehov omfatter udelukkende behovet for selve arbejdspladsen onshore.

3.4 Nødvendigt maskinel

I Tabel 3.3 er anført en oversigt over nødvendigt maskinel, der skal anvendes i forbindelse med etablering af foringsrør og af kabler. Oversigten skal betragtes som et estimat og afhænger af den enkelte entreprenørs tilgængelige maskinpark. Antallet af hver enkelt enhed er ikke vurderet.

Tabel 3.3: Oversigt over potentielt nødvendigt maskinel ved etablering af foringsrør og itrækning af kabler. Der skelnes mellem etablering af foringsrør ved styret underboring og gravning.

Ilandføringsmetode / Potentielt nødvendig maskinel	Ilandføring gennem foringsrør etableret ved gravning	Ilandføring gennem foringsrør etableret ved opgravningsfri metode
Flydepram og/eller jack up-rig	x	x
Entreprenørskib	x	x
Afviser- og bugserfartøjer	x	x
Spulevogn (ROV)	x	
HDD borerig		x
Slamcontainer		x
Slamsuger og vandvogn		x
Gravemaskiner	X	x
Rendegraver	X	
Dumpere	X	x
Rammemaskine	X	x
Svejseapparater	X	x
Trækspil	X	x
Generator	X	x
Mandskabsvogne	X	x
Dykkere	X	x
Diverse håndmaskinel (f.eks. pladevibrator, jordloppe osv.)	X	x

Efter endt etablering, vil arbejdsarealet til lands og til vands blive reetableret.

3.5 Retablering af arbejdsareal

Uagtet den endelige udførelselsmetode, vil retableringen af arbejdsarealer betrages som en nødvendig opgave idet onshore arealer vil blive berørt i større eller mindre omfang.

Arealerne for entreprisen henligger primært som mere eller mindre uberørte muldbelagte jorder og dels befæstede arealer i form af veje. Der vil i forbindelse med arbejderne blive anvendt arbejdsmetoder og materiel, således at der belægninger og installationer mv. indenfor entrepriseområdet ikke beskadiges.

Arealet ryddes i et omfang svarende til det for arbejdet nødvendige areal, herunder afrømning, fjernelse af vegetation og diverse inventar, som måtte være til hinder for arbejdets udførelse. Der vil blive sikret tilstrækkelig dokumentation for arealernes beskaffenhed forud for opstart, herunder ved eksempelvis at lade udføre droneoverflyvning for opmåling og fotodokumentation.

Eventuelt genindbygningsegnet jord samt udstyr og inventar indenfor entrepriseområdet vil blive nedtaget og deponeret for senere genanvendelse.

Arealer med muld rømmes og mulden køres til midlertidigt deponi for senere genudlægning på arealet. Alle berørte arealer, herunder befæstede arealer der ikke befæstes på anden vis ifm. tilstødende opgaver, eksempelvis for etablering af transformerstation på land, vil blive retableret til samme beskaffenhed og stand som før arbejdets påbegyndelse.

3.6 Tidsplan

Afhængig af anlægsmetoden og antallet af kabler, der skal ilandføres forventes anlægsarbejderne at forløbe over en periode på 6-8 måneder inkl. mobilisering, svejsning, boring/gravning, afrapportering og afrigning.

Tidsplanen kan blive opdelt i flere etaper, såfremt myndighedskrav fordrer, at der er perioder, hvor der ikke må arbejdes af hensyn til dyre og planteliv - specielt til vands.

PART 3: ONSHORE / ANLÆG PÅ LAND

1 Introduktion

Det forventes, at transformering af spændingen produceret i Aflandshage Vindmøllepark vil finde sted på land, og dette er forudsat i den tekniske anlægsbeskrivelse herunder. Det er dog en mulig løsning for transformeringen vil finde sted offshore ved anlæg af en samlet transformerstation i Aflandshage Vindmøllepark. Dette er der redegjort for i Part 1 Offshore. Ved transformering offshore skal der kun ilandføres ét 132 kV kabelsystem, som tilsluttes ved Avedøreværket på Energinets 132 kV koblingsstation.

De landbaserede dele af anlægget omfatter landkabler, mulig ny transformerstation og tilslutning til den eksisterende station i eltransmissionsnettet ved Avedøreværket. Ved anlæg af en fuldt udbygget vindmøllepark på 300 MW og anlæg af transformerstation på land vil kabelanlægget på land bestå af følgende:

- Fra kysten og frem til en kystnær transformerstation installeres op til 6 stk. 33 kV eller 66 kV kabelsystemer ved fuldt udbygget vindmøllepark på 300 MW. Systemerne installeres enkeltvis i flad forlægning i en rør-/kabelgrav. Arbejdsbæltet ved installation af rør-/kabelgrav er op til 9 m bredt, når kabelsystemerne installeres enkeltvis som 6 parallelle kabelsystemer. Det efterfølgende servitutbelagte areal er op til 12 m bredt ved anvendelse af 6 kabler i flad forlægning med en afstand på op til 1 m mellem hvert kabelsystem. Ved anvendelse af 4 stk. 66 kV kabelsystemer i flad forlægning vil anlægsbæltet tilsvarende være 8 m bredt og servitutbæltet samlet 12 m bredt. Afstanden fra kysten til transformerstationen ønskes så kort som muligt.
- Fra transformerstationen tilsluttes strømmen det eksisterende elnet ved Energinets 132 kV station ved Avedøreværket ved installation af et 132 kV kabel. Arbejdsbæltet er op til 5 m bredt, og det efterfølgende servitutbelagte areal vil være ca. 4 m bredt.

Landkablerne graves ned og vil ved Avedøreværket omfatte 33 kV eller 66 kV kabler og 132 kV kabler. På det nævnte servitutbelagte areal omkring kablerne, må der ikke opføres bebyggelse, foretages anlægsarbejder uden HOFORs tilladelse eller etableres beplantning med dybdegående rødder.

De landbaserede dele af anlægget vil som nævnt ovenfor omfatte muligt anlæg af en ny kystnær transformerstation, hvorfra strømmen fra vindmøllerne (tilsluttet med mellem 3 og 6 søkabler) føres videre i et enkelt 132 kV kabel til eksisterende stationsanlæg ved Avedøreværket lidt længere inde i landet.

Tilslutningen af vindmøllerne til det eksisterende eltransmissionsnet sker i eksisterende stationsanlæg på land ved Avedøreværket. Dette er tilfældet uanset, om der anlægges en ny kystnær transformerstation eller ej. Tilslutningen kræver udvidelse af det eksisterende stationsanlæg. Udvidelsen består i forlængelse af eksisterende koblingsanlæg ved etablering af et nyt felt i Avedøreværkets 132 kV højspændingsanlæg. Der vil således ikke være behov for arealudvidelser i forbindelse med tilslutningen til 132 kV anlægget ved Avedøreværket.

Den mulige placering af en ny transformerstation samt udvidelsen af eksisterende stationsanlæg på land beskrives i detaljer i afsnit 3.

2 Kabelanlæg

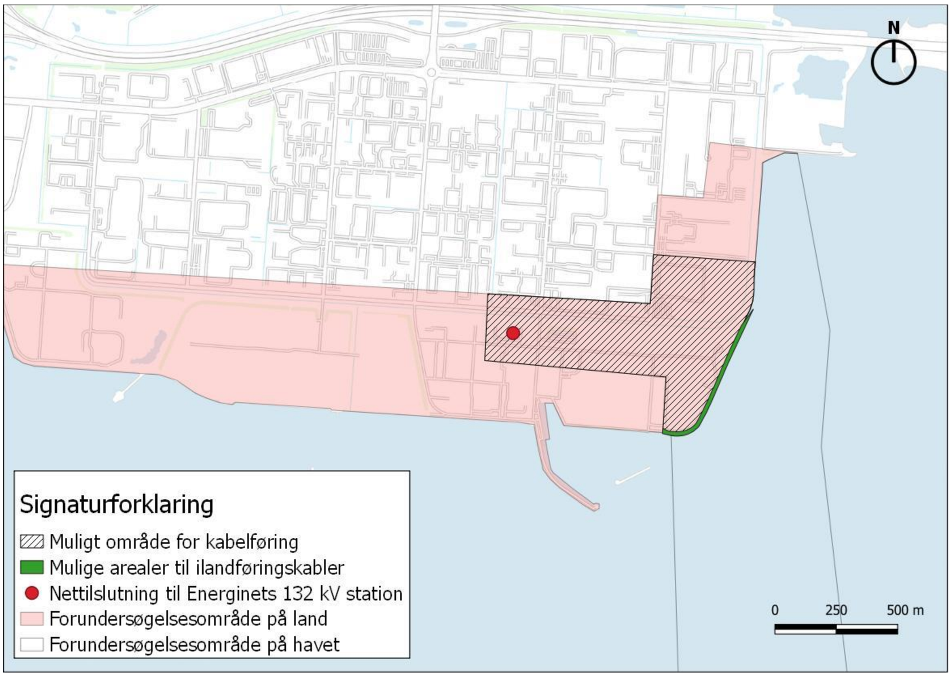
2.1 Kabelstrækninger

Ilandføring kan finde sted i henhold til to følgende principper:

a) Da transformerstationen er placeret i umiddelbar nærhed af ilandføringspunktet, kan søkablerne føres direkte ind i stationen og tilsluttes 33/66 kV koblingsanlægget uden brug af overgangsmuffer fra søkabel til landkabel.

b) Ilandførte søkabler samles med de landkabler, der skal føre strømmen fra Aflandshage Vindmøllepark ilandføringspunkt frem til nettilslutningspunktet ved Avedøreværket (se 3.3). Det planlagte område, hvor der kan placeres landkabler i jorden, fremgår af Figur 2.1.

Figur 2.1: Område for installation af nedgravede kabler på land ved Aflandshage. © SDFE



2.2 Kabelanlægget

Et kabelanlæg karakteriseres ved:

- Spændingsniveauet
- Antallet af kabelsystemer og højspændingskabler
- Lysledere
- Jordledere
- Forlægningsmønsteret, - der er et udtryk for, hvordan kablerne placeres i kabelgraven
- Kabelmaterialer og kabellængder
- Bredde af arbejdsbælte langs kabelanlægget i anlægsfasen
- Bredde af deklarationsbæltet langs kabelanlægget i driftsfasen

Til installation af kabelanlægget vil der være behov for et antal anlægsmaskiner herunder en gravemaskine til udgravning af rør-/kabelgrav. Eventuelt en vogn med sand og en rendegraver til tildækning af rør og lukning af rør-/kabelgrav. Et spil eller kabelspulesystem til efterfølgende installation af kablerne i de for-installerede rør. Hertil kommer et antal traktorer, lastbiler og rendegravere til alle de logistiske opgaver.

På Avedøre Holme vil kabelstrækningen på land næppe overstige 1,5 km. Der vil således kun være behov for få kabeltromler og disse kan leveres løbende til anlægsområdet. Der er derfor ikke behov for etablering af plads til opbevaring af kabeltromler. Kabelanlæggene på land vil afhængigt af valgt projektalternativ omfatte:

- Op til 6 stk. 33 eller 66 kV kabelsystemer, transformerstation og et 132 kV kabel
- Et 132 kV kabelsystem (ved anlæg af offshore transformerstation)

I dette projekt består hvert kabelsystem af tre faser, der skal ligge i én rør-/kabelgrav i forventet flad forlægning med 1 m afstand mellem hvert kabelsystem. Et eksempel på et 132 kV kabelsystem fremgår af Tabel 2.1. Kabelsystemet omfatter:

- Enfasede kabler lagt i trekant forlægning.
- 1-3 tomrør til trækning af lyslederkabel til kommunikation og eventuelt temperaturmålinger.

Tabel 2.1: Eksempel på tekniske data for et 132 kV kabelsystem.

Teknisk data for 132 kV kabelsystem	
Jævnstrøm / vekselstrøm	Vekselstrøm
Spændingsniveau [kV]	132 kV
Kabelsystemer [stk.]	1
Højspændingskabler [stk.]	3
Lysleder [stk.]	1
Lægningsmønster	Flad eller trekant forlægning
Kabelmateriale	Aluminium eller kobber leder med PEX isolation
Kabellængder på tromle [m]	ca. 1.000 m - 2.500 m

Højspændingskablerne leveres fra fabrikken som enkeltledere på tromler. Hver kabeltromle kan indeholde én kabellængde, der erfaringsmæssigt er på mellem 1.000 – 2.500 m pr. tromle og har en vægt på op til 20 tons. Som tidligere nævnt forventes der ikke oplag af kabeltromler i kabelkorridoren.

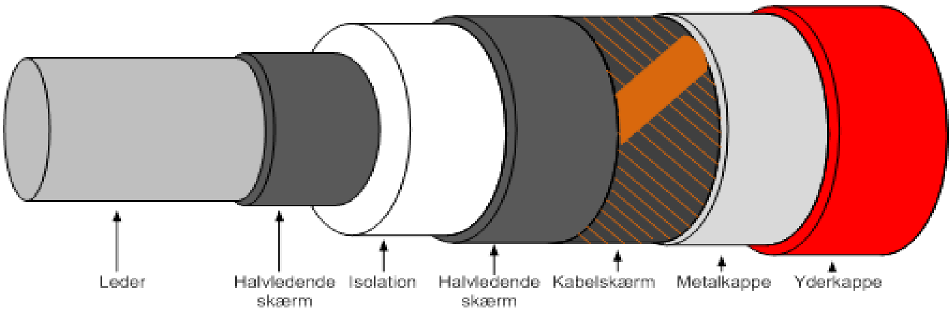
Et typisk 132 kV højspændingskabel er opbygget som angivet i Figur 2.2. Opbygningen består af:

- Inderleder, aluminium eller kobber.
- Halvledende lag, der er med til at styre det elektriske felt i kablet.
- Isolation, XLPE ”cross linked Polyethylene”.
- Halvledende lag for styring af det elektriske felt i kablet.
- Skærm af kobber- eller aluminiumstråde og/eller aluminiumsfolie.
- Metalkappe, der sikrer radial vandtæthed.
- HDPE kappe (High Density PolyEthylen).

Hvert kabel består af en aluminiums- eller kobberleder omgivet af et trippel-ekstruderet isolerende plastmateriale. Herefter er der lagt en skærm omgivet af et lag af vandstoppende bånd på hver side, og som en sikring mod vandgennemtrængning er der lagt en aluminiumsfolie. Den yderste kappe er i polyethylen og fungerer som mekanisk beskyttelse.

Såfremt kablet grundet skade eller anden årsag skal erstattes, er der ikke nogen forureningsmæssig risiko ved evt. brud og senere skrotning, da der ved XLPE-kabler er tale om såkaldte faste materialer, såsom plast og metaller, og det drejer sig derfor ikke om flydende materialer, som ved eksempelvis olie-isolerede kabler. Dette betyder, at der ved skrotning af XLPE isolerede kabler følges den normale procedure for sortering og granulering hos en oparbejdningsanstalt.

Figur 2.2: Eksempel på opbygning af et højspændingskabel[21]



Kabler på de øvrige spændingsniveauer (33 kV og 66 kV) er opbygget på samme måde som 132 kV kablet vist i ovenstående eksempel. De forskellige spændingsniveauer adskiller sig primært ved forskellig tykkelse af XLPE isolationslaget.

2.2.1 Lyslederkabler

Lyslederkabler ligger i samme kabelgrav som højspændingskablerne. Udover muffesamlingerne (se afsnit 2.2.4) vil der få steder indenfor forundersøgelsesområdet være behov for at etablere en brønd til lyslederkablet. Brøndene bliver nedgravet i 1-1,5 m dybde, de vil være ca. 1,5 m i diameter.

2.2.2 Anlægsarbejdet generelt

Når der anlægges el-kabler i byzone sker dette typisk ved en forudgående installation af tomrør som el-kablerne efterfølgende installeres i. I byzone vil der ikke være plads til anlægsbælter med oplag af jord, og åbne kabelgrave over længere strækninger er ikke hensigtsmæssigt. Tomrørene installeres typisk enkeltvis i længder på 12 m pr. rørelement, hvorefter rørgraven lukkes og åbne kabelgrave over længere strækninger derved undgås. El-kablerne itrækkes eller indspules herefter i tomrørene over strækninger på op til 600–1.200 m. For at en itrækning/indspuling er mulig, må tomrør ikke trykkes flade eller have krumninger, der er mindre end en radius 5 m. Krydsningen af eksisterende infrastruktur og skarpe bøjninger af kabelruten vil medføre behov for at samle kortere kabelstrækninger med kabelmuffer (se afsnit 2.2.4).

Kabelgraven vil som udgangspunkt være omkring 1,4 m dyb og 1 m bred. Bunden i kabelgraven kan fores med 5-10 cm sand og i øvrigt tilbagefyldes den opgravede jord i rør-/kabelgraven, når kablerne er beskyttede af det for-installerede tomrør. Der anvendes op til ca. 10 m^3 sand for hver 100 m kabeltracé ved installation med den beskrevne metode.

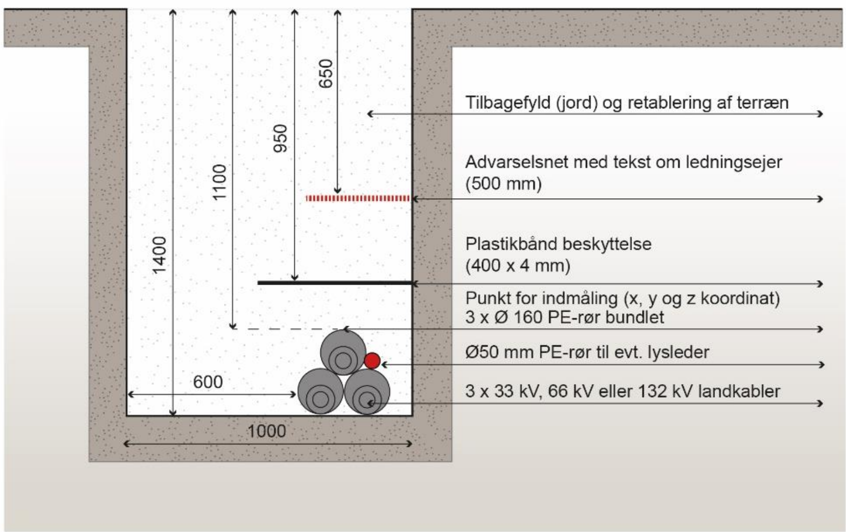
Udgravning for højspændingskabel imellem vindmølletransformerstation og Energinet's 132 kV station har en udstrækning på ca. 1.000 m, og det forventes at anlægget udføres i 2 etaper á 500 m. Kabler forventes udlagt efter opgravning, hvorefter udgravning tildækkes og terræn retableres. Udgravning og retablering for hver etape forventes at udføres over en periode på 1 måned.

[21] Energinet 2015, Sejerø Bugt Havmøllepark. Projekt- og anlægsbeskrivelse, anlæg på land. Rapport nr. 13/98200-1

Der foretages udgravning for kabler kommende fra vindmølleparken fra ilandføringspunktet til transformerstationen. Afstanden fra ilandføring til transformerstationen er ca. 350 m. Udgravningen forventes at udføres i 2 etaper. Udgravningen og retablering for hver etape forventes udført over en periode på ca. 2 måneder.

Der skal foretages udgravning for spildevandsledning, vandledning og elforsyning til transformerstationen. Udgravningen vil blive etableret som en fælles udgravning for de nævnte forsyningsanlæg. Anlæggets udstrækning er på ca. 500 m og forventes udført i 2 etaper af ca. 250 m. Forsyningsanlæggene forventes udlagt efter opgravning, hvorefter udgravning tildækkes og terræn retableres. Udgravning og retablering for hver etape forventes at udføres over en periode på 1 måned.

Figur 2.3: Rør-/kabelgrav som den typisk vil være udformet. Kabler er dog her lagt i trekant forlægning installeret i tomrør ses i bunden af rør-/kabelgraven[22]



Ved installation af flere parallelle kabelsystemer placeres de med en indbyrdes afstand på forventet op til 1 m, når der installeres i flad forlægning. Det betyder, at et eventuelt servitutbælte omkring kablerne vil øges med 1 m for hvert kabelsystem, der tilføjes. Installeres der 6 parallelle 33 eller 66 kV kabelsystemer fra kysten og frem til transformerstationen vil det samlede servitutbælte således være op til 12 m bredt. Ved installationen af ét 132 kV kabelsystem vil servitutbæltet være ca. 2 m på hver side af kablet.

Arbejdsområdet ved installation af nedgravede tomrør vil typisk være rør-/kabelgravens bredde samt den bredde langs rør-/kabelgraven, som er nødvendig for at operere gravemaskiner, lastbiler til jord, materiel mv. langs rør-/kabelgraven og således 5–10 meter bredt.

Sker anlægsarbejdet på sårbart underlag (fliser, græsplæne og lignende) udlægges eventuelt jernkøreplader for at beskytte belægning/jordbund mod trykskader. Over de installerede rør lægges et kraftigt rødt plastik dækbånd til mekanisk beskyttelse af kabelsystemet. Omkring 65 cm under det færdige terræn udlægges et advarselsnet med tekst, som angiver ejerskab af kabler, kontaktoplysninger mv.

Råjorden fyldes tilbage og komprimeres for at undgå luftlommer omkring kabelsystemet, og til sidst lukkes kabelgraven med muldjord, eller eksisterende belægning retableres.

[22] Kabelhåndbogen. AC-kabelanlæg 132-400 kV. Energinet 2018

Der er meget lidt overskudsjord i forbindelse med anlægsarbejdet, og det vil efterfølgende blive fordelt ud over tracéet eller bortskaffet.

I områder med skrånende arealer, hvor der kan opstå en uønsket drænvirkning i sandlaget i bunden af kabelgraven, kan der lægges propper af ler (bentonit), der bryder sandlaget og dermed forhindrer horisontal drænvirkning. Dette forventes ikke at være relevant ved kabelanlæg på Avedøre Holme.

Kabelgraven vil med den anvendte metode kun stå åben ganske kortvarigt og på meget korte strækninger svarende til længden af rørelementer, da opgravning af rør-/kabelgrav, nedlægning af rørelementerne og tilbagefyldning og tildækning sker i én arbejdsgang.

Efter anlægget er færdigt, vil det eventuelt være omfattet af et servitutbelagt bælte med en bredde på 4 m omkring kabelsystemet, der skal tinglyses på de berørte ejendomme. I det servitutbelagte bælte må der ikke opføres bebyggelse eller etableres beplantning med dybdegående rødder. Aktiviteter som gravearbejder indenfor servitutbæltet må kun iværksættes efter aftale med kabelejeren, som vil være HOFOR A/S.

2.2.3 Kabeludlægning

Kabeludlægning foregår ved, at kabeltromlerne transporteres i en specialfremstillet kabelvogn, der kører tromlen ud til kabelkorridoren. Ved anlæg i byområder sker installationen af kabler typisk ved at kablerne trækkes via wire eller spules ind i det/de allerede installerede tomrør. Indspuling af kablerne sker med vandtryk på op til 10 bar og ved anvendelse af lette kabler med aluminiumsleder kan der spules kabler i tomrør på op til 1000 meters længde. Ved itrækning med spil placeres dette i den modsatte ende af tomrørs sektionen. Derefter trækkes kablerne ind i tomrørene i flad forlægningen enkeltvis.

Itrækning af 1 kabellængde udføres med en hastighed på ca. 1-2 m/min. I hver kabelgrav installeres 1-3 tomrør (d = 40 mm) til lyslederkabler sammen med tomrør til kablerne, hvor dette er relevant. Senere kan der blæses lyslederkabler ind i disse rør, dels til temperaturovervågning af kablet, dels til kontrolfunktion af elforbindelsen. Lyslederinstallationerne følger kabeltracéet.

2.2.4 Muffearbejde

For hver kabellængde skal kablerne muffes sammen. Antallet af nødvendige kabelmuffer afhænger af udformningen af det endelige kabeltrace og antallet af skarpe bøjninger og komplicerede krydsninger af eksisterende infrastruktur. Det er dog sikkert, at de ilandførte søkabler skal muffes med landkablerne tæt ved ilandføringen. Dette arbejde foregår ved hjælp af montagetelt. Arbejdsperioden for muffearbejdet til en muffegruppe, det vil sige samling af de tre kabler i kabelgraven (3 muffesamlinger), er ca. 5-6 arbejdsdage.

Selve samlingen af kablerne med muffer giver ikke nødvendigvis anledning til installationer over terræn, da installationerne kan være nedgravet ca. 1,5 meter under terræn.

2.2.5 Midlertidige kørespor

Udover det arbejdsspor der bliver etableret langs med kabelgraven, vil der sandsynligvis være behov for at benytte et antal midlertidige køreveje for at få adgang til kabeltracéet fra eksisterende veje. Disse kørespor anvendes til transport af kabeltromler, sandfyld, materiel mv.

2.2.6 Grundvandssænkning

På strækninger med højt grundvandsspejl kan der trods den forventede installationsmetode med korte strækninger med åbne rør-/kabelgrave af kort varighed muligvis opstå et behov for at sænke grundvandet midlertidigt om ikke andet, hvor kabler skal muffes sammen. En grundvandssænkning kan ske enten ved installering af sugespidsanlæg (kun ved sandrige jordbundsforhold), ved forudgående nedpløjning af et plastdræn i og under kabelgraven (ca. 2,0 m under terræn) eller ved lænsepumpning. Plastdrænet tilsluttes en række pumper placeret langs kabelgraven med passende afstand. Når kablerne er lagt, lukkes plastdrænet, så det ikke længere bliver benyttet.

Hvis der er tale om en mere lokal forekomst af vandrige jordlag foretages oppumpningen eventuelt via et sugespids-anlæg direkte i kabelgraven. For begge metoder gælder, at det oppumpede vand ikke må ledes direkte til søer eller vandløb, da der kan ske sedimentspredning eller spredning af stoffer, som skader vandmiljøet.

Langs kabeltracéet vil der sandsynligvis kun være tale om helt lokale grundvandssænkninger ved særligt komplicerede krydsninger af eksisterende infrastruktur og af meget begrænset varighed (1-2 dage). Ved muffesamlinger på kablerne kan der være tale om grundvandssænkninger på op til 10 dages varighed.

Muligheden for afledning af det oppumpede grundvand til det tilstødende kystvandområde ved Avedøreværket via de eksisterende kanaler undersøges. Hvis ikke direkte afledning til overfladevand kan ske, belyses afledning til kloak eller anden bortskaffelse.

2.2.7 Kabellægning ved underboring

De steder, hvor det ikke er hensigtsmæssigt eller muligt at kabellægge ved nedgravning, kan kablet blive installeret ved en styret underboring. Ved styret underboring opnås bl.a., at kritisk infrastruktur, sårbar natur, veje, beskyttede diger og evt. læhegn ikke bliver påvirket af gravearbejdet.

Underboring sker med særligt boregrej, som kræver etablering af en arbejdsplads på ca. 50 m² i den ene ende af underboringen, samt en mindre plads af samme størrelsesorden til sammensvejsning af plastforingsrør i den anden ende af underboringen. Underboringen sker normalt inden installation af rør-/kabelgrav på resten af strækningen. Ved underboring til kystområdet uden for diget vil anlægsarbejdet i det lavvandede kystområde, hvor underboringen slutter, ske fra specialfartøj, hvor søkablerne trækkes ind i underboringen og til landsiden af diget, hvor søkablet samles med overgangsmuffer med landkablet.

Underboring sker ved, at der bores et rørformet hul i jorden, i hvilket der placeres et plastforingsrør for hvert kabel. Kablet trækkes derpå igennem foringsrøret, og foringsrøret fyldes efterfølgende med bentonit. Dette gøres af hensyn til kravet om varmeafledning fra kablerne. Den udvendige diameter kan ligge mellem 200 mm og 300 mm. Dette kan dog ændre sig under projekteringen af projektet.

Ved styret underboring anvendes boremudder, der består af en opslæmning af ler (fx bentonit), der under boringen pumpes ned og rundt i borehullet for at reducere friktion og transportere borematerialle til overfladen. Bentonit er en naturligt forekommende lerart, der består af ca. 50% siliciumdioxid (SiO_2), 20% aluminiumtrioxid (AlO_3), 3% jernoxid (Fe_2O_3) samt oxider af calcium, magnesium, natrium og kalium, plus krystalvand (ca. 5%). Herudover kan borevæsken være tilsat forskellige komponenter for at optimere egenskaberne, fx baryt, salt, organiske polymerer.

Normalt er underboringer mellem 15-300 meters længde. I særlige situationer kan længere strækninger dog underbores helt op til 1.000 meter. Der er flere forhold, som afgør den mulige længde af en underboring, og det er derfor nødvendigt at lave en konkret vurdering i hvert enkelt tilfælde.

Jordbundsforholdene kan være afgørende for, om underboring kan udføres. For at fastlægge et boreprofil kan der udtages enkelte jordbundsprøver. Forundersøgelserne skal medvirke til en sikker gennemførelse af underboringen og mindske risikoen for blow-ups; det vil sige, at boremudderet (bentonit) skyder op i det terræn, som boringen føres under.

2.2.8 Krydsning af fremmede lednings- og røranlæg

Kabelanlæggets krydsning af fremmede ledninger eller rør udføres på forskellige måder, alt efter hvad der skal krydses, og hvilke krav den givne ledningsejer har til krydsninger. Den enkleste metode er frigravning og understøtning af den krydsede ledning, hvor kabelanlægget kan udtrækkes under. En anden mulighed er frigravning af den krydsede ledning og udlægning af trækrør til kabelanlægget, hvorefter den krydsede ledning kan tildækkes før udtrækning af kabelanlægget. Den mest omfattende krydsningsmetode er styret underboring, som fortrinsvis benyttes, hvis der er tale om krydsning af større lednings- eller røranlæg.

2.3 Anlægsarbejdernes varighed og anvendelse af maskiner

Den forventede varighed af anlægsarbejder i forbindelse med kabellægning er vurderet til maksimalt 5-6 måneder, men vil afhænge helt af kompleksiteten og antallet af komplicerede krydsninger af eksisterende infrastruktur. Længden af kabeltracé på land vil dog maksimalt være 1,5 km.

Til etablering af et 132 kV kabelanlæg vil der være behov for et antal anlægsmaskiner. Der er herunder i Tabel 2.2 angivet et skønnet omfang af antal og typer af maskiner, som vil blive anvendt i anlægsperioden. Til installation af kabelanlæg med lavere spændingsniveau skal samme type maskiner anvendes, dog i mindre omfang.

Tabel 2.2: Overslag på antal og typer af anvendte maskiner samt forventet varighed til anlæg af kabler.

Skønnet antal og type af maskiner til anlæg af kabler
2-3 stk. gravemaskiner, 14 til 32 tons
2 stk. dumpere
2 stk. traktorer
4 pladsbiler
1 lastbil
1 gummiged
2 underboringsmaskiner
1 slamsuger
3-5 lastbiler for udlægning af køreplader
1 trækspil
1 blokvogn til levering af kabeltromler på depoter langs tracéet
2-3 lastbiler til levering af sand på depoter langs tracéet

Den overslagsmæssige opgørelse har til formål at give et indtryk af størrelsesordenen af trafikarbejdet og driftstiden ved anvendelse af entreprenørmaskiner.

De angivne maskiner vil ikke nødvendigvis blive anvendt kontinuert igennem anlægsarbejdet men kun på de tidspunkter, hvor deres tilstedeværelse er påkrævet.

Antallet af timer, som maskinerne skal anvendes i pr. døgn, vil afhænge af forholdene under anlægsarbejdet.

2.4 Aktiviteter i driftsfasen

Kabler vedligeholdes ikke. Der sker derfor ingen aktiviteter på kabelstrækninger i driftsfasen, medmindre kablet rammes af en fejl. Hvis et kabel går i stykker, så graves ned til det fejlramte sted. Det fejlramte stykke af kablet fjernes og erstattes med et nyt kabelstykke. Kablet samles med muffer. Der anvendes samme procedure som ved installation af kablet. Kabelfejl forekommer sjældent, og som hovedregel kun på grund af ydre påvirkninger som gravearbejder, der sker for tæt på kablerne.

2.5 Demontering af kabelanlæg

Den forventede levetid for kabelsystemer er ca. 40 år, og kablesystemer skrottes, når isoleringen er nedbrudt. I forbindelse med demontering af kabler vil der foregå arbejder af samme karakter og omfang som i anlægsfasen.

Der vil være behov for et arbejdsareal på maksimalt ca. 10 meter langs med kabeltracéet. Der etableres kørevej langs kabelrenden, eventuelt ved hjælp køreplader, hvis det er nødvendigt.

Herefter opgraves kablerne, og de afskæres i passende længder, således at de kan blive transporteret fra arbejdsområdet til en dertil egnet oparbejdningsanstalt. Kablerne er opbygget af såkaldte faste materialer, såsom plast og metaller og indeholder derfor ikke flydende materialer, som ved eksempelvis olie-isolerede kabler. Der er derfor ikke nogen forureningsmæssig risiko ved opgravning af kabelsystemet.

Kablerne kan genbruges i miljøgodkendte anlæg. Metallet frigøres med henblik på genbrug, og plastisolationen fjernes fra metaller ved afskæring. Plastmaterialet kan findeles og genbruges ligesom metallerne.

De steder, hvor kabelsystemet er installeret ved en styret underboring, kan kablerne trækkes tilbage ud af underboringen, og rørene vil herefter blive fyldt med bentonit og forseglet.

2.6 Materialeforbrug til kabler

Nedenfor er angivet hvilke materialer, som et kabel består af (Tabel 2.3) samt anslået forbrug til henholdsvis 33 kV, 66 kV og 132 kV kabler (Tabel 2.4).

Tabel 2.3: Anvendte materialer til kabler.

Type	Materiale
Ledermateriale	Aluminium (Al) eller kobber (Cu)
Ledertype	Massiv Runde tråde/komprimeret Profiltråde Segmenteret/Milliken
Lederskærm	Ekstruderet lag af halvledende materiale
Isolation	Ekstruderet PEX (krydsbundet polyætylen)
Isolationsskærm	Ekstruderet lag af halvledende materiale
Metallisk skærm	Al-/Cu-tråde i modspiral mod lederens tråde Foldet Al-laminat til radial vandtæthed (Svejset og/eller limet, kan erstatte tråde)

Type	Materiale
Langsgående vandtætning	Kvældbånd under og eller over skærmtrådende
Kappe	Ekstruderet PE, som regel med et ydre halvledende lag, med markering (tekst)

Der er ligeledes angivet et anslået materialeforbrug til kabler.

Tabel 2.4: Anslået materiale-forbrug.

Materialer	Forbrug	Maksimal længde
33 kV kabler (aluminium, polyætylen)	ca. 120 tons pr. 3 km. kabelsystem (3 faser)	6 stk. á 500 m
66 kV kabler (aluminium, polyætylen)	ca. 80 tons pr. 2 km. kabelsystem (3 faser)	6 stk. á 500 m
132 kV kabler (aluminium, polyætylen)	ca. 150 tons pr. 1,5 km. kabelsystem (3 faser)	1 stk. á 1.500 m

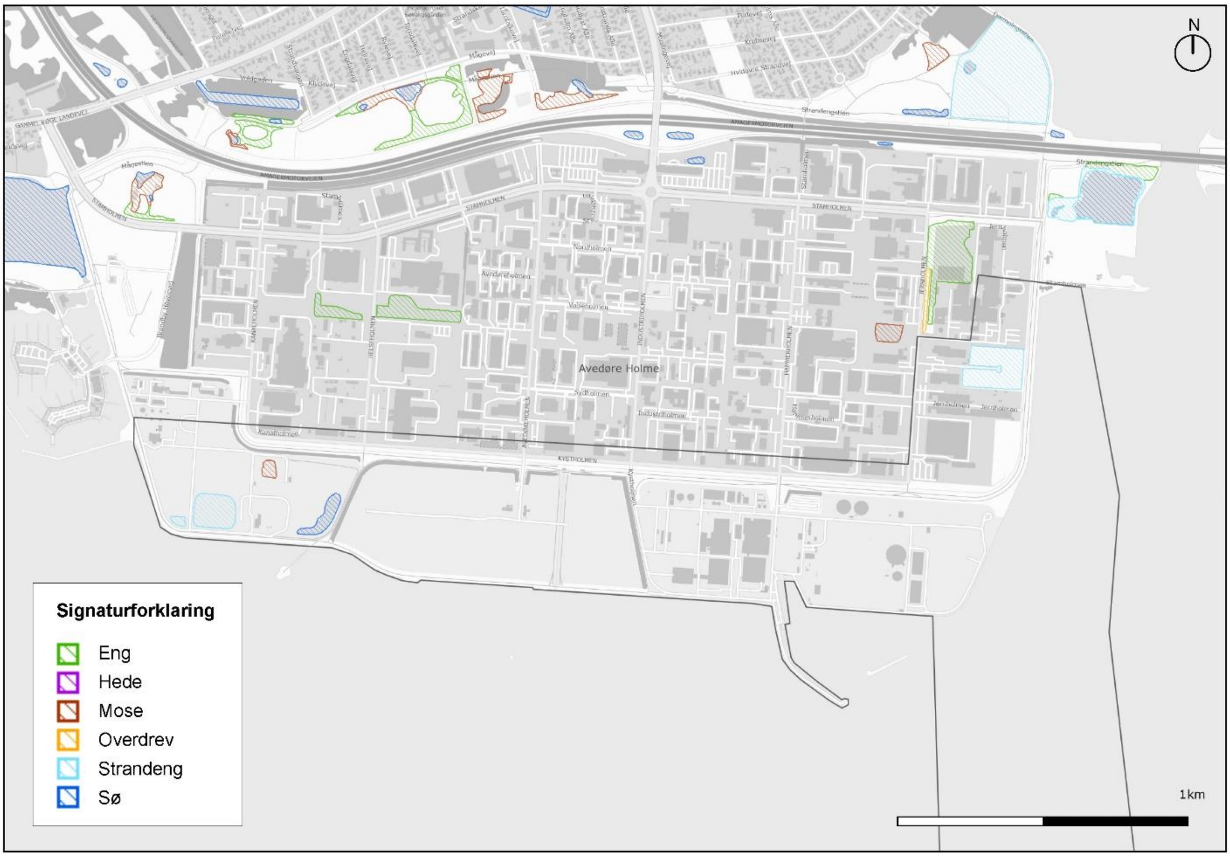
2.7 Fokusområder

Beskyttede naturtyper og herunder fx vandløb, beskyttede diger, infrastruktur mv. har betydning for placeringen af landkabler, der som udgangspunkt skal udgå disse eller krydse strækninger som vandløb, diger og eksisterende infrastruktur ved etablering af underboringer (se afsnit 2.2.7)

Af nedenstående Figur 2.4 fremgår beskyttede naturtyper, som findes i området omkring forundersøgelsesområdet. Naturområderne er udpeget i henhold naturtypebekendtgørelsen[23].

[23] BEK nr. 1067 af 21/08/2018. Bekendtgørelse om beskyttede naturtyper (naturtypebekendtgørelsen).

Figur 2.4: Oversigt over beskyttede naturtyper i og omkring forundersøgelsesområdet på land. ©SDFE, WMS-tjeneste, dæmpet skærmkort. Indeholder data, som benyttes i henhold til vilkår for brug af danske offentlige data.



3 Stationsanlæg

3.1 Generelt

I forbindelse med nettilslutningen af vindmølleparken skal der foretages udvidelser i eksisterende stationsanlæg og anlægges en ny transformerstation:

- **Ny transformerstation**: Ilandføringskablerne kan bestå af op til 6 stk. 33 eller 66 kV kabelsystemer. For at mindske både investeringer og elektriske tab i nettilslutningsforbindelsen planlægges ilandføringskablerne forbundet til en transformerstation så tæt på ilandføringspunktet som muligt, hvor spændingen transformeres op til det spændingsniveau, som passer til det eksisterende eltransmissionsnet. Dette vil omfatte anlæg af en ny transformerstation, hvorfra strømmen fra vindmøllerne føres videre i et enkelt 132 kV kabel til Energinets eksisterende 132 kV stationsanlæg ved Avedøreværket, såfremt der ikke anlægges en offshore transformerstation (se del 1, afsnit 4).

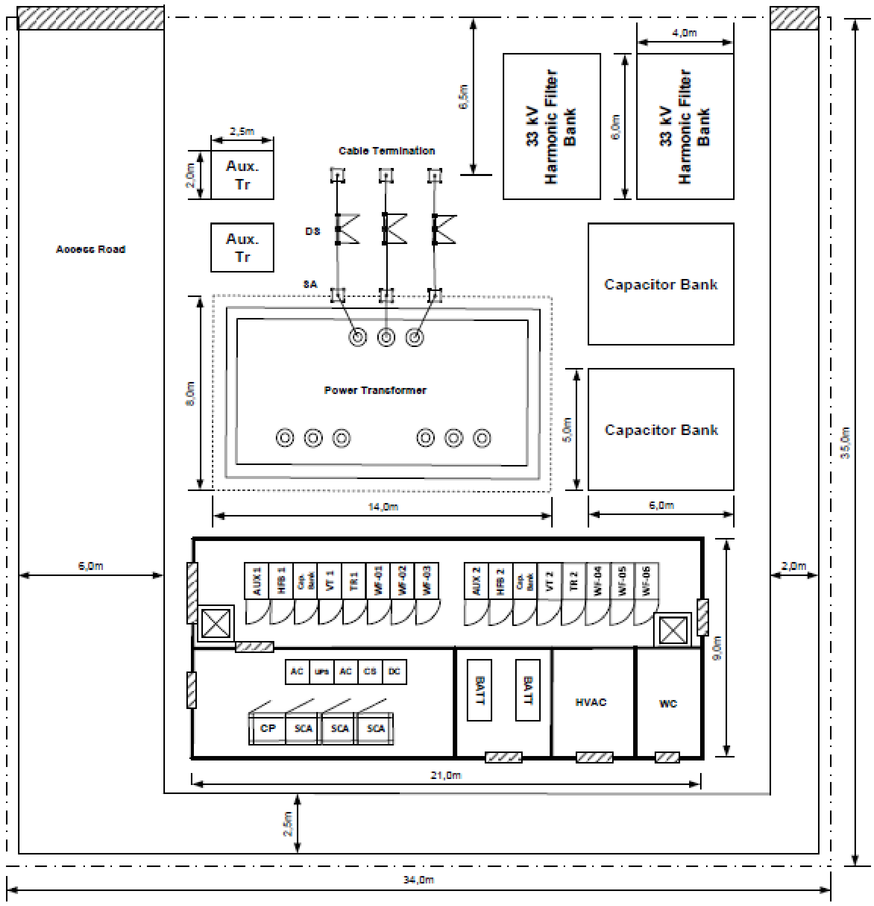
- **Udvidelse af eksisterende stationsanlæg**: Tilslutningen af vindmøllerne til det eksisterende eltransmissionsnet sker i et eksisterende stationsanlæg på land i Energinets 132 kV station ved Avedøreværket. Tilslutningen kræver en udvidelse af det eksisterende 132 kV anlæg i den eksisterende bygning. Udvidelsen udgøres af en forlængelse af eksisterende koblingsanlæg ved tilføjelse af et ekstra felt på stationernes samleskinner, hvortil kablerne kan tilkobles og vil således ikke kræve udvidelse af eksisterende bygninger.

3.2 Ny transformerstation

Der skal anlægges en ny transformerstation, hvor kabelsystemerne (antal afhænger af valgt vindmøllealternativ) samles og efterfølgende transformeres til 132 kV der videreføres i et enkelt 132 kV kabel til Energinets eksisterende 132 kV stationsanlæg ved Avedøreværket.

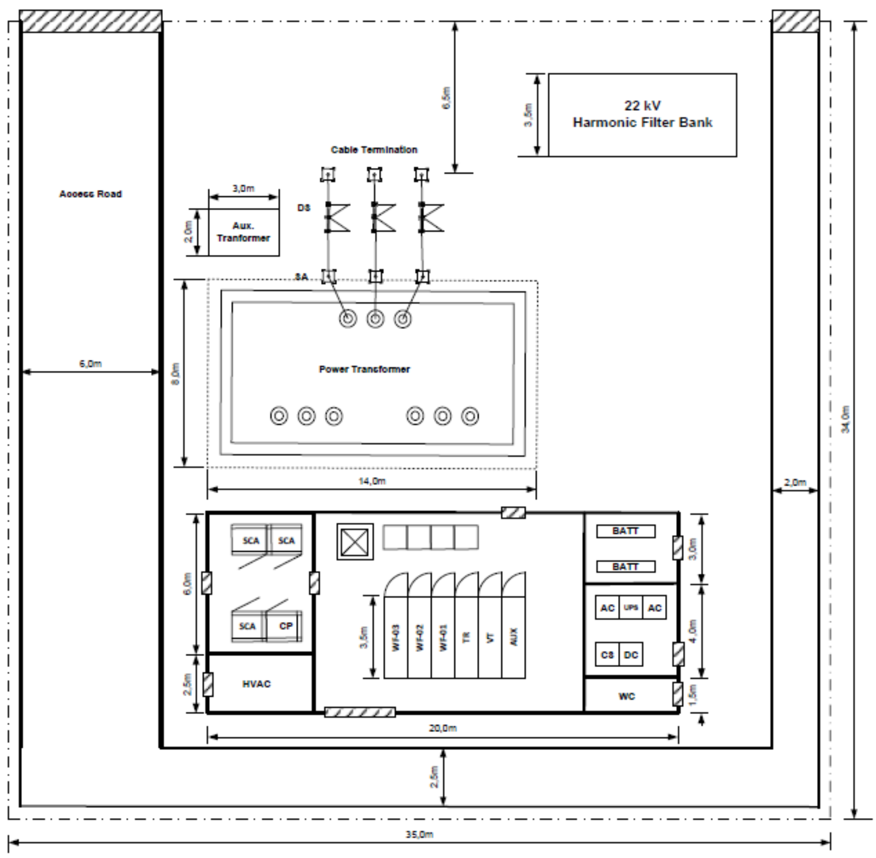
I de følgende afsnit gives generelle beskrivelser af en ny transformerstation. Derudover behandles udbygning af de eksisterende stationsanlæg ved Avedøreværket i forbindelse med nettilslutning (afsnit 3.3). Transformerstation og tilhørende kabler anlægges af HOFOR Vind A/S.

En principskitse for opbygningen af en ny transformerstation, der kan omfatte op til to transformere, samleskinner samt bygninger til afbrydere, kontrolanlæg, hjælpeudstyr, toilet mv., fremgår for hvert af de tre vindmøllestørrelser på hhv. Figur 3.1, Figur 3.2 og Figur 3.3. Principskitserne er udarbejdet af COWI for HOFOR Vind A/S.

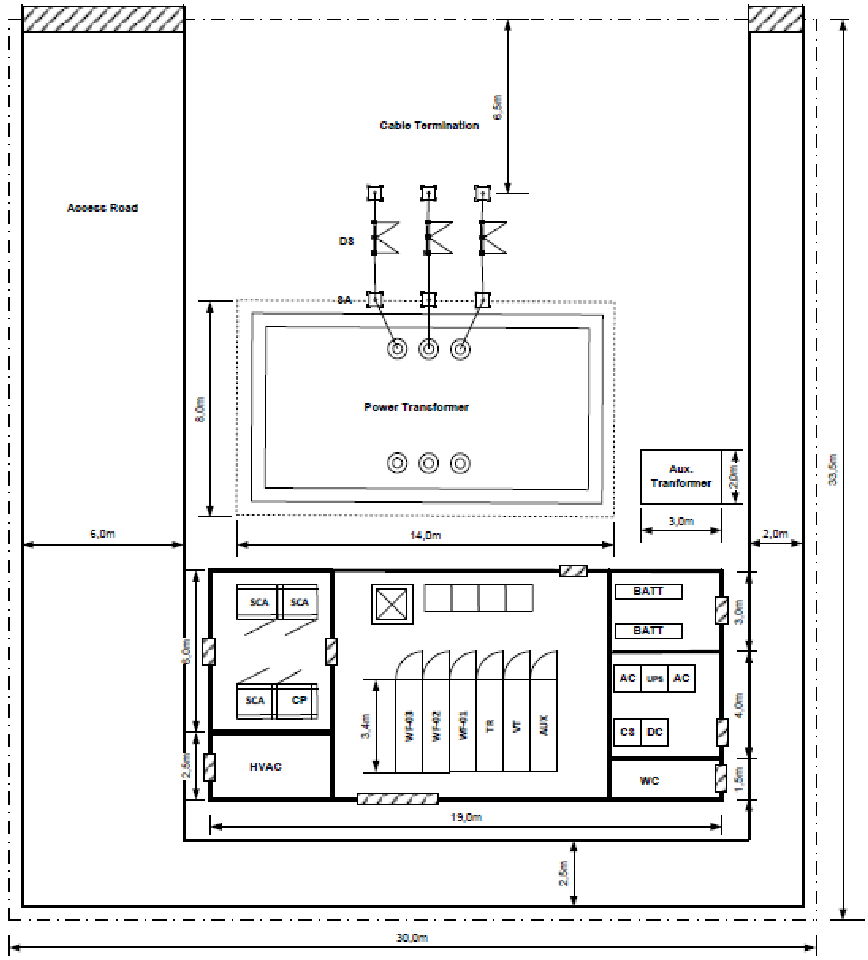


Figur 3.1: Principskitse af ny transformerstation for scenarie med lille vindmølle. Areal og indretning kan afvige i det endelige projekt.

Figur 3.2: Principskitse af ny transformerstation for scenarie med mellem vindmølle. Areal og indretning kan afvige i det endelige projekt.



Figur 3.3: Principskitse af ny transformerstation for scenarie med stor vindmølle. Areal og indretning kan afvige i det endelige projekt.



Transformerstationens størrelse afhænger af den endelige valgte vindmøllestørrelse, da der kan være behov for at installere elektrisk kompenseringsudstyr som sikrer strøm og spændingskvaliteten. Stationen tænkes udført som et delvist lukket anlæg bestående af en bygning som huser teknisk udstyr samt 33/66 kV koblingsanlæg. Udstyr som transformere, kompenseringsudstyr og 132 kV adskiller vil blive opstillet udendørs. Stationsbygningen forventes at have en størrelse på minimum 200 m². Det samlede areal for stationsområdet forventes at have et areal på 1.000-1.600 m². Samlet højde på anlægget vil være 7 m over færdigt terræn. Stationen vil, af sikkerhedsmæssige årsager, blive indhegnet og kan evt. afskærmes yderligere med støjregulerende foranstaltninger.

Stationen vil rumme et 33 kV eller 66 kV GIS-opkoblingsanlæg (Gas Insulated Switchgear), batterianlæg, simpel stationskontrol, fjernkontrol, fiberinstallation og relætavler. Desuden vil den skulle bestå af en enten 33/132 kV eller 66/132 kV udendørs transformer, som på grund af sit behov for elektrisk isolation og køling indbygges i en ståltank fyldt med op til 75 m^3 olie. Da den er oliefyldt, vil den skulle placeres på et fundament med et reservoir, der kan rumme hele oliemængden. Ved eventuel lækage lukker udskilleren, og al olien tilbageholdes i reservoiret. Samtidig afgives alarm til døgnbemandet kontrolrum hos vindparkoperatøren. Der forventes således ingen risiko for udledning af olie til miljøet.

Endvidere vil der skulle etableres et eventuel kompenseringsanlæg til sikring af strøm og spændingskvalitet. Kompenseringsanlægget vil bestå af reaktive kompenseringsenheder, jordingstransformere, spoler og andet mindre udstyr. Kompenseringsanlægget vil være maksimalt 7 m over færdigt terræn. Reaktive kompenseringsenheder og jordingstransformere vil tilsvarende udendørs hovedtransformer skulle indbygges i oliefyldte tanke med et samlet indhold på op til 80 m^3. Funktion og lækagerisiko er som beskrevet i afsnittet herover, og der forventes således ingen risiko for udledning til miljøet.

Stationsanlægget skal beskyttes af et lynafledningsanlæg bestående af stålmaster samt lynfangere som regnes placeret i periferien af stationen i 4-6 punkter. Lynfangere skal placeres således at de beskytter de højeste placerede anlægsdele hvorved lynfangere vil være placeret højere end de angivne 7 m over terræn.

Stationsanlægget vil endvidere blive stormflodssikret for en 1000 års hændelse ved at hæve bygningen 1 meter over terræn (se afsnit 4 nedenfor).

Arealbehov til en ny GIS transformerstation vil være op til 2.000 m^2, herunder inklusive areal til parkering af servicevogn samt kran og blokvogn ved udskiftning af eventuelle defekte komponenter.

Etablering af transformerstationsområdet, som omfatter byggemodning, terrænregulering, anlæg af tilkørselsveje og evt. afvanding kan normalt gennemføres i en periode på 8-10 uger. Der vil blive udført geotekniske undersøgelser til fundering af bygning.

3.2.1 Forventet placering af ny transformerstation

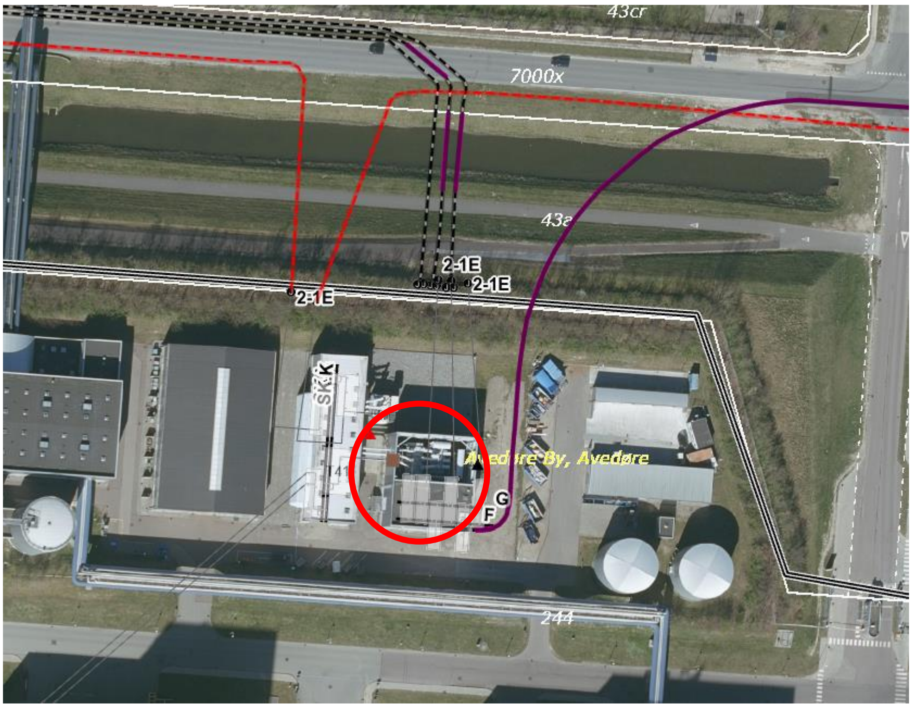
Transformerstationen forventes placeret i den sydøstlige ende af matrikel 244 ved Avedøreværket. Det store frie areal øst for biopillelager. De konkrete afstandskrav til biomasselageret skal undersøges. Sikkerhedsafstand i forhold til nyt, fremtidigt lager medtages. I dette tilfælde føres søkablerne i land og direkte op til transformerstationen, og 132 kV kablet til nettilslutning føres langs Kystholmen til det aftalte tilslutningspunkt.

Figur 3.4: oversigtskort over den forventede placering af transformerstationen (blå områder). ©SDFE, WMS-tjeneste, Ortofoto 2020.

3.3 Tilslutning til elnettet ved Avedøreværket

Tilslutningen til det eksisterende elforsyningsnet sker i Energinets eksisterende 132 kV stationsanlæg ved Avedøreværket (Figur 3.5). Stationsanlægget udvides med et ekstra felt til tilslutning af vindmølleparken.

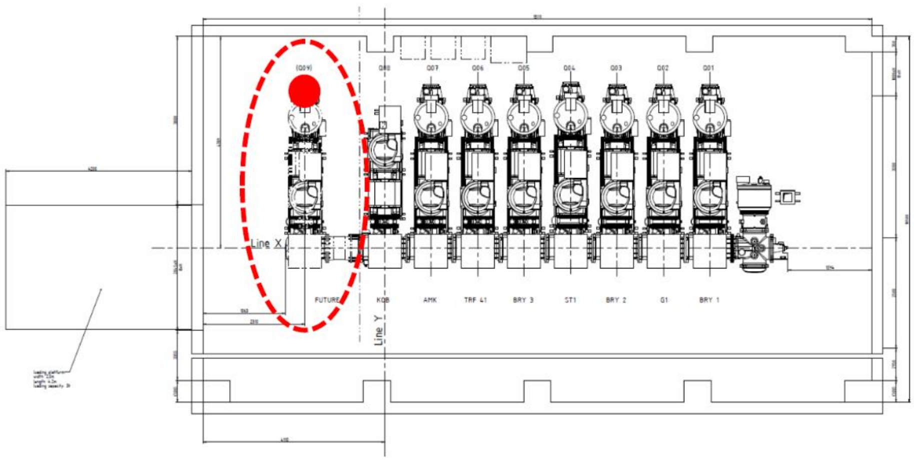
Figur 3.5: Markering af Energinets eksisterende 132 kV stationsanlæg på matrikel nr. 244, Avedøreværket (rød ring). Energinets eksisterende 132 kV kabel er vist med lilla.



Udvidelserne af Energinets eksisterende 132 kV stationsanlæg ved Avedøreværkets vil kunne foretages inden for det eksisterende stationsområde.

Det eksisterende gasisolerede højspændingsanlæg (GIS-anlæg) udvides med et ekstra GIS-felt, som installeres i direkte forlængelse af det eksisterende GIS-anlæg (Figur 3.6). Det eksisterende GIS-anlæg anvender gassen SF_6 (Svovlhexafluorid) som isoleringsmiddel, hvorfor feltet for tilslutning af Aflandshage Vindmøllepark også vil anvende SF_6 gas som isolationsgas.

Figur 3.6: Principskitse af tilslutningsfeltets placering i den eksisterende 132 kV stationsbygning. Det nye GIS-felt er markeret med stiplet rød markering, og selve tilslutningspunktet med en rød prik.



3.4 Anlægsarbejde

Til anlæg af ny transformerstation vil der være behov for et antal anlægsmaskiner. Der er herunder angivet et skønnet omfang af antal og typer af maskiner, som vil blive anvendt i anlægsperioden (Tabel 3.1). Opgørelsen skal betragtes som overslagsmæssig med det formål at få et indtryk af størrelsesordenen af anvendelse af entreprenørmaskiner. De angivne maskiner vil ikke nødvendigvis blive anvendt kontinuert igennem anlægsarbejdet men kun på de tidspunkter, hvor deres tilstedeværelse er påkrævet.

Tabel 3.1: Overslag på antal og type af anvendte maskiner samt forventet varighed for til anlæg af ny transformerstation.

Station	Skønnet antal og type af maskiner	Forventet varighed
Ny transformerstation	1 gravemaskine, 7 til 32 tons 2 rendegravere/minigraver 1 lastbil / dumper 1 gummiged 1 traktor med kran/ lastbil med kran 1-2 person lifte	6-12 måneder

Det angivne byggepladsareal på ca. 60x100 m vil inkludere skurfaciliteter, affaldshåndtering samt materialeoplag. Byggeplads og adgangsveje er angivet på Figur 3.7.

Figur 3.7: Konceptuel illustration af byggepladsareal.

Der bliver etableret tilslutning til eksisterende kloaksystem til brug for afledning af vand fra byggegrubber samt tilslutning til eksisterende strøm- og vandforsyning, som angivet på Figur 3.8. Tilslutningerne vil bliver etableret for senere brug i driftsfasen også.

Figur 3.8: Tilslutninger fra transformerstationen til eksisterende strøm- og vandforsyning.

Der vil i forbindelse med anlæggelse af transformerstationen blive foretaget gravearbejder i forbindelse med etablering af byggepladsområde samt bygning og fundamenter. De estimerede opgravede materialemængder i forbindelse med terrænregulering er 1.800 m³ (ved 30 cm terrænregulering) og for anlæggelse af bygning og øvrige fundamenter er 600 m³.

Adgangen af maskiner vil foregå gennem Avedøreværkets hovedport.

3.4.1 Jordhåndtering

Der graves ud med anlæg underkant af bundplade og ledningstraceér. Det opgravne jord lægges i depot på matriklen, fordelt i fraktioner (muld, råjord, aske, sand mv).

Efter bygningsdelene er udført omkringfyldes der med aske fra depot omkring bygningen, og der afsluttes med muld. Omkring ledningerne udføres der et ledningsbed i sand med en tykkelse på omkring 30 cm over og under ledningerne, hvorefter der fyldes op med aske eller råjord og afsluttes med muld.

Sand og grus kan genbruges såfremt det er genbygningsegnet, ellers køres det bort og nyt tilfyldningsmateriale køres til.

Under adgangsvejen skal der opbygges en vejkasse på omkring 50-70 cm i nyt tilfyldningsmateriale (stabilgrus).

Overskydende aske kan bruges til at udføre terrænregulering på matriklen eller bortskaffes.

3.4.2 Grundvandssænkning

Der skal udføres udgravninger til transformerstation. Der forventes anvendt fri udgravning, hvor udgravninsgsarealet i bunden måler ca. 10x6 m. Der forventes behov for at grave ca. 3 m ned i forhold til eksisterende terræn.

Terræn ligger i kote ca. +2,5 m. Der skal derfor udgraves til kote -0,5 m. Der forventes et grundvandsspejl beliggende mellem kote ca. 0 meter, svarende til vandspejlet i havet, og kote ca. -2,5 m, svarende til vandspejlet i kanalerne på Avedøre Holme. Der findes to dybere boringer i nærheden; DGU nr. 208. 1531 og 208. 5814. Disse viser begge hhv. ler og moræneler/morænesand mellem kote ca. -1,5 og -7,5 m. Herover findes tynde aflejringer af ukendt beskrivelse eller sand. Oversiden af disse lag ligger omkring kote -0,8 m, hvilket stemmer overens med, at havdybden var ca. 0,8 m i området, inden arealet blev inddæmmet.

Der forventes ikke behov for en egentlig grundvandssænkning, men der vil være behov for at tørholde byggegruben i forhold til nedbør samt indsivning af vand fra de øverste jordlag. Dette kan forventeligt klares med lænsning alene. Skulle det vise sig, at der er områder, hvor der sker en lidt større indsivning fra de øverste jordlag, kan der være behov for at anvende sugespidser her. Baseret på erfaring skal der bortledes <10 m^3/t. Sænkningen forventes maksimalt at sprede sig 100 m fra byggegruben grundet den begrænsede sænkning samt den korte afstand til hhv. kanaler og kyst.

Skulle det vise sig, at der er områder, hvor der sker en lidt større indsivning fra de øverste jordlag, kan der være behov for at anvende sugespidser her. Baseret på erfaring skal der bortledes <10 m^3/t. Sænkningen forventes maksimalt at sprede sig 100 m fra byggegruben grundet de lavpermeable jordlag samt den korte afstand til hhv. kanaler og kyst.

3.5 Materialeforbrug og råstoffer til anlæg af transformerstation

Til anlæg af ny transformerstation vil der være behov for en vis mængde materialer og råstoffer, samt fjernelse af råjord. De forventede maksimale mængder fremgår af nedenstående Tabel 3.2.

Tabel 3.2: Forventede materialemængder til anlæg af ny transformerstation.

Station	Materiale	Skønnet mængde
Ny transformerstation	Råjord Grus Beton (fundamenter) Armeringsstål Stål galvaniseret	1.000 m^3 4.000 m^3 300 m^3 8 tons 16 tons

3.6 Drift af ny transformerstation

3.6.1 Støj

I driftsfasen kan der være støj fra transformerstationen. Støjen er ikke konstant, men vil afhænge af spændingen og meteorologiske forhold. Der anlægges ingen nye strækningsanlæg som luftledninger i dette projekt.

Højspændingstransformerstationen og koblingsanlæg vil være indendørs anlæg i en lukket bygning. I højspændingssystemet er der følgende støjkilder:

- Hovedtransformeren
- Lokalforsyning anlæg
- Ventilationsanlæg

Der er udført orienterende støjberegning for udendørs placering af transformerstationen (Uhre & Nybæk, 2021). Støjberegningen viser, at med et lydeffektkrav på 90 dB(A) for transformeren, vil støjbelastningen fra denne, ligge væsentligt under grænseværdierne uden for matriklen. Det nærmeste støjfølsomme område er naturområdet Kalvebod Fælled, som er regnet for rekreativt område med grænseværdi på 40 dB(A) i dagtimerne og 35 dB(A) resten af tiden.

Nedenfor er indsat tabel over støjbelastningen på udvalgte positioner.

	Støjbelastning	Grænseværdi nat
	dB(A)	dB(A)
Industri nord	38,9*	70
Nordskel ved P-plads	18,5*	70
Ørsted AVV	59,2*	70
Hvidovre Strandvej 189	8,4	35
Amager sti syd	22,6*	35

Kabelanlægget udsender som nævnt ingen akustisk støj i drift.

3.6.2 Belysning

Stationen drives ubemandet. Det er muligt, at der installeres en form for svagt orienteringslys. Der installeres desuden et udendørs arbejdslys, som tændes manuelt.

3.6.3 Trafik og anden drift

Stationen vil kun være bemandet i forbindelse med periodisk vedligehold, inspektioner og reparationer. Den forventede hyppighed er samlet 3-4 dage pr. år. Det forventede antal personer er mellem 1-3, når stationen er bemandet.

3.7 Afvikling af stationsanlægget

Højspændingssystemet indeholder store mængder olie og drivhusgasser, som skal håndteres korrekt, når komponenterne skal bortskaffes.

Olien tappes ud, regenereres og kan genbruges. Drivhusgasserne fra koblingsanlægget opsamles ved hjælp af et specielt gas-håndteringsanlæg og kan herefter genanvendes eller bindes i fast form.

Der udarbejdes en "end of life" strategi for samtlige komponenter på stationen. Strategien bliver en del af drifts- og vedligeholdelsesmanualen.

Nedtagning og nedlæggelse af transformerbygningen vil følge de til enhver tid gældende regler.

4 Stormflodsikring

4.1 Baggrund

HOFOR vind ønsker at etablere en transformerstation på Avedøre Holme og ønsker i den forbindelse at se på risikoen for oversvømmelse fra hav og ekstrem regn.. Anlægget er planlagt til at skulle have en levetid på 35 år inkl. etablering. Det er undersøgt hvad sikringsniveauet for en 1.000 års hændelse i år 2056 forventes at være samt risikoen for oversvømmelse i dag.

4.2 Eksisterende sikring omkring transformerstation

Der er et eksisterende jorddige omkring sitet med en kote ~4,8 m med varierende højde på +-10cm. I syd er der en kort strækning, hvor sikringen er i kote ~4,2 m. Desuden er der en åbning i diget så man kan få adgang til sitet i kote ~2,5 m, hvilket skal kunne lukkes i en beredskabssituation eller der skal etableres en rampe man kører over ind til grunden.

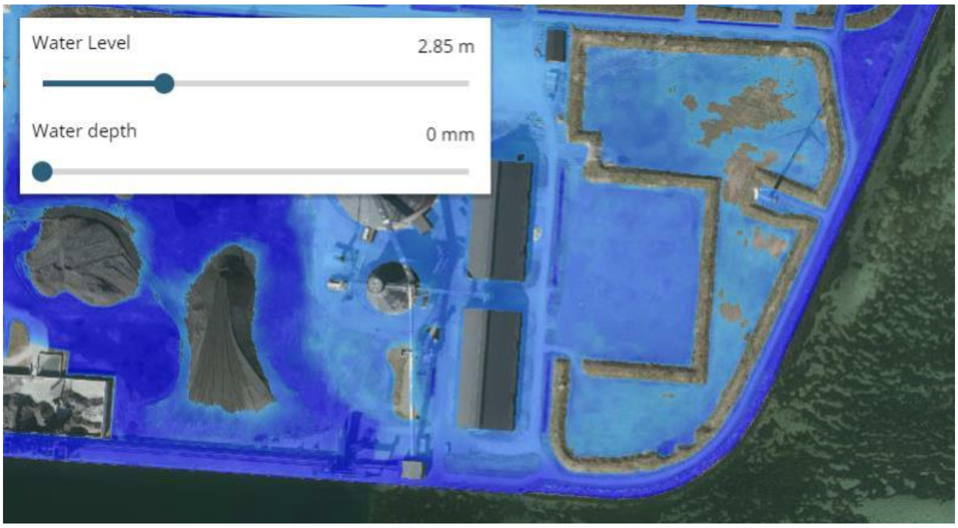
4.3 Risiko for oversvømmelse fra regn for tranformerstation

Hele området fremstår i dag ukloakeret og er omringet af en ~2,1 m jordvold. Selve grunden hælder lidt mod syd og det sammenholdt med jordvolden gør, at regnvand ikke kan strømme mod transformerstationen. Derfor etableres et kloaksystem, som kan afvande selve grunden og sikre at man kan aflede til nærliggende kloak.

4.4 Risiko for oversvømmelser fra stormflod for transformerstation

Såfremt man ikke laver nogle tiltag vil området bliver oversvømmet når vandet når en kote svarende til 2,85 m, se Figur 4.1. En sådan kote svarer i dag til en hændelse med en gentagelses periode på ~350 år, hvilket forventes at falde til en ~270 års hændelse i 2056, grundet klima forandringer og stigende havvand.

Figur 4.1: Oversvømmelse af site ved kote 2,85 m.



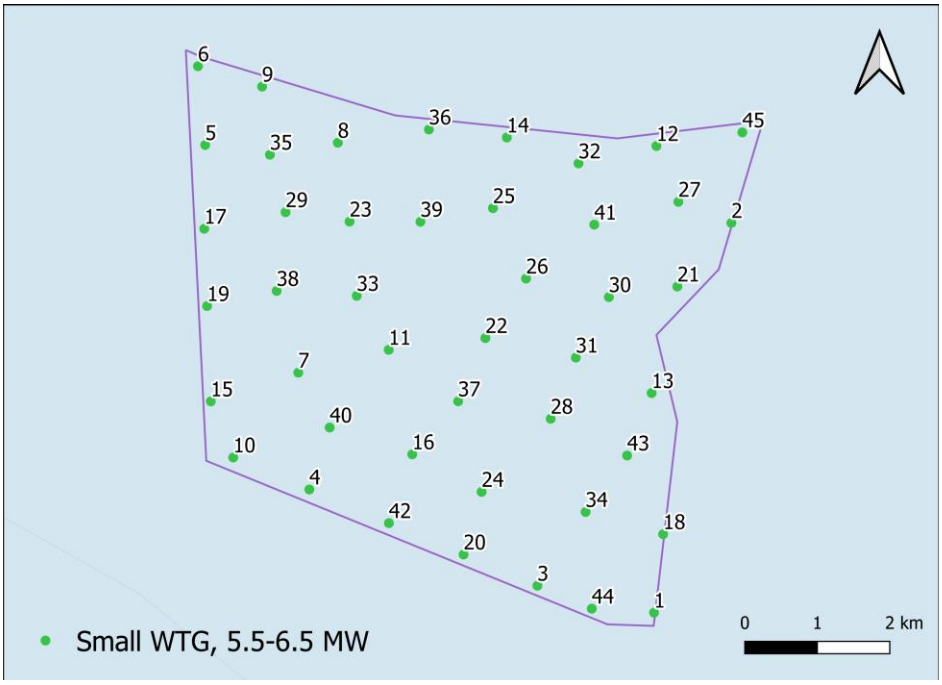
4.4.1 Mulig sikring til en 1.000 års hændelse i 2056

Såfremt anlægget skal sikres for en 1.000 års hændelse i år 2056 skal anlægget enten hæves eller digerne omkring sitet skal kunne holde vandet ude. Median koten for en 1.000 års hændelse i 2056 ved Avedøreholme er ~3,9 m.

For transformerstationen er det planlagt at sikre selve anlægget, som bygges på et forhøjet fundament på omkring 1 m, da det nuværende terræn ligger i kote 2,9 m. Inde på land vil man kunne forvente små bølger som der tages højde for ved udformningen af fundamentet, så disse ikke skader installationen.

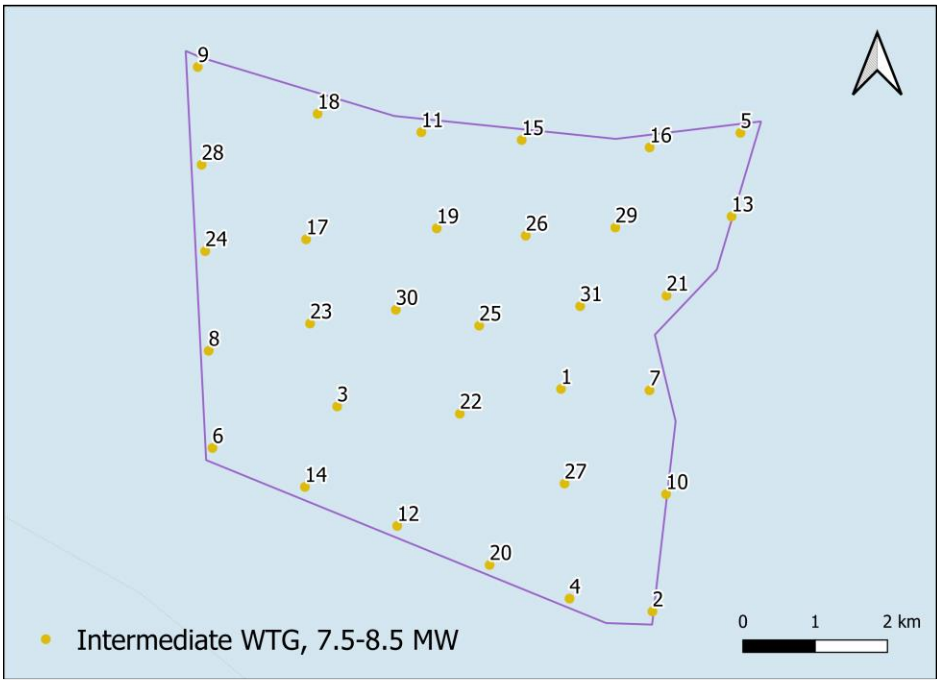
Appendix 1: Possible wind turbine positions

A.1.1: Possible 5.5-6.5 MW wind turbine layout for Aflandshage Wind Farm.



A.1.2: Possible positions of the small 5.5-6.5 MW wind turbine.

WTG	UTM – ETRS89 zone 32		WTG	UTM – ETRS89 zone 32	
	Easting	Northing		Easting	Northing
1	728297	6144874	24	725918	6146541
2	729364	6150253	25	726074	6150457
3	726688	6145246	26	726531	6149485
4	723541	6146574	27	728633	6150545
5	722104	6151329	28	726871	6147550
6	722004	6152416	29	723213	6150401
7	723388	6148187	30	727674	6149230
8	723934	6151360	31	727218	6148394
9	722889	6152135	32	727255	6151075
10	722491	6147016	33	724195	6149247
11	724636	6148502	34	727353	6146264
12	728330	6151315	35	722998	6151195
13	728264	6147905	36	725191	6151543
14	726266	6151432	37	725594	6147791
15	722181	6147790	38	723090	6149315
16	724961	6147059	39	725074	6150270
17	722091	6150173	40	723822	6147429
18	728423	6145957	41	727472	6150229
19	722130	6149106	42	724639	6146110
20	725669	6145676	43	727926	6147043
21	728619	6149375	44	727438	6144929
22	725970	6148664	45	729515	6151503
23	724096	6150272			

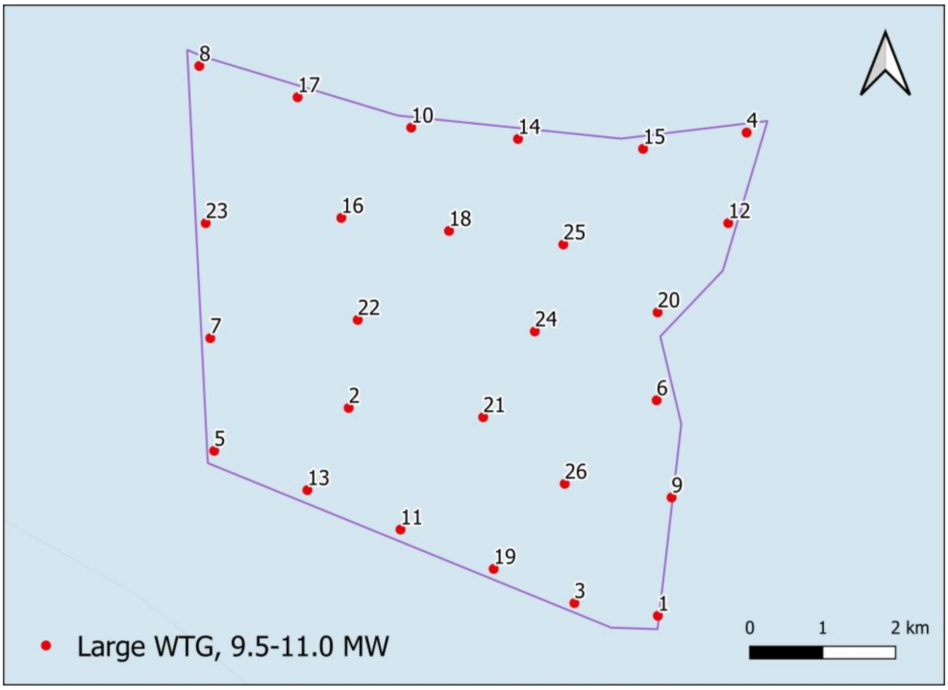


A.1.3: Possible 7.5-8.5 MW wind turbine layout for Aflandshage Wind Farm.

A.1.4: Possible positions of the intermediate 7.5-8.5 MW wind turbine.

WTG	UTM – ETRS89 zone 32		WTG	UTM – ETRS89 zone 32	
	Easting	Northing		Easting	Northing
1	727031	6147956	17	723503	6150029
2	728297	6144874	18	723662	6151768
3	723933	6147714	19	725311	6150181
4	727149	6145051	20	726043	6145518
5	729515	6151503	21	728492	6149248
6	722207	6147138	22	725630	6147613
7	728256	6147937	23	723558	6148862
8	722154	6148485	24	722106	6149865
9	722003	6152417	25	725899	6148833
10	728486	6146499	26	726543	6150080
11	725098	6151513	27	727080	6146645
12	724764	6146058	28	722057	6151062
13	729392	6150346	29	727783	6150193
14	723486	6146599	30	724745	6149053
15	726487	6151405	31	727296	6149103
16	728258	6151302			

A.1.5: Possible 9.5-11 MW wind turbine layout for Aflandshage Wind Farm.

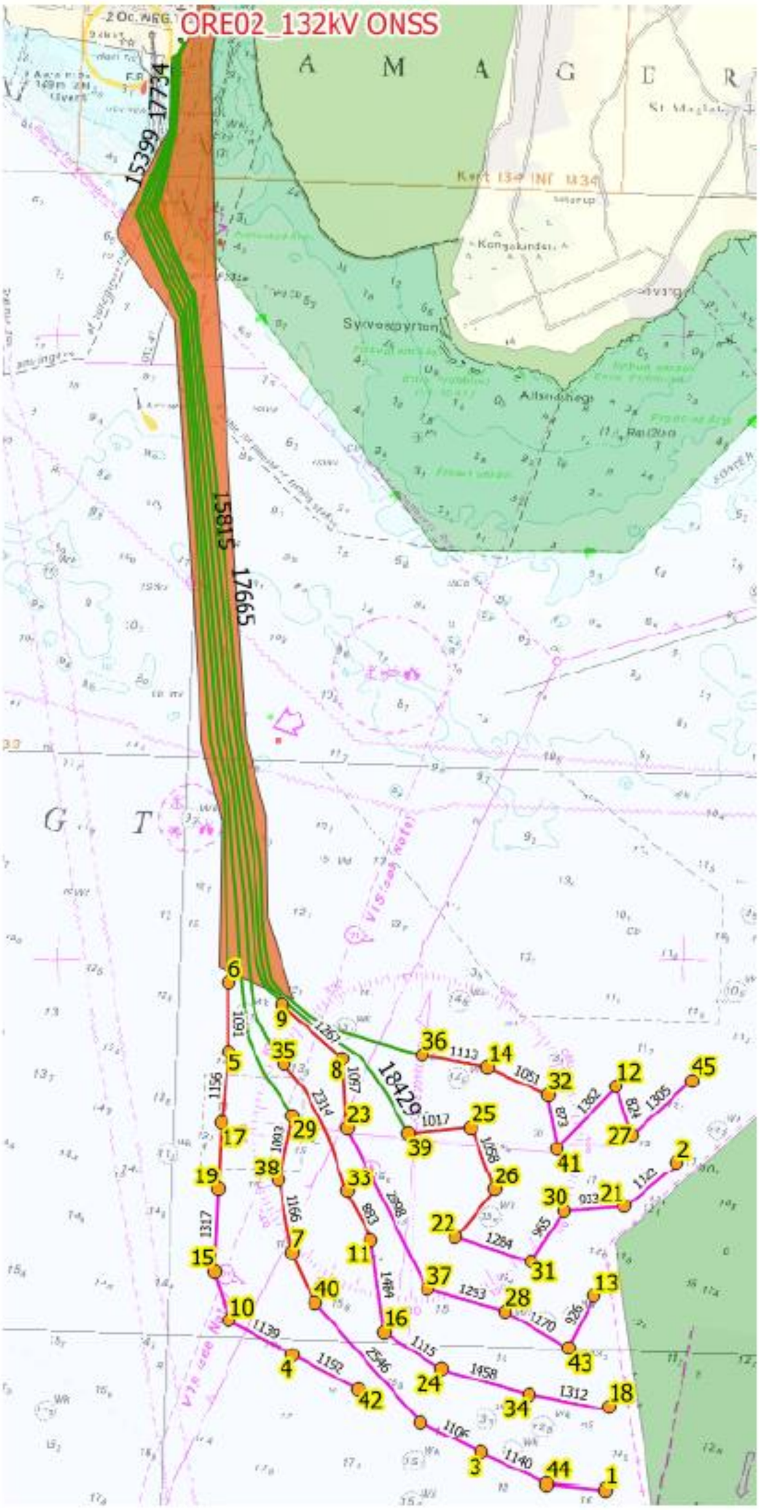


A.1.6: Possible positions of the large 9.5-11.0 MW wind turbine.

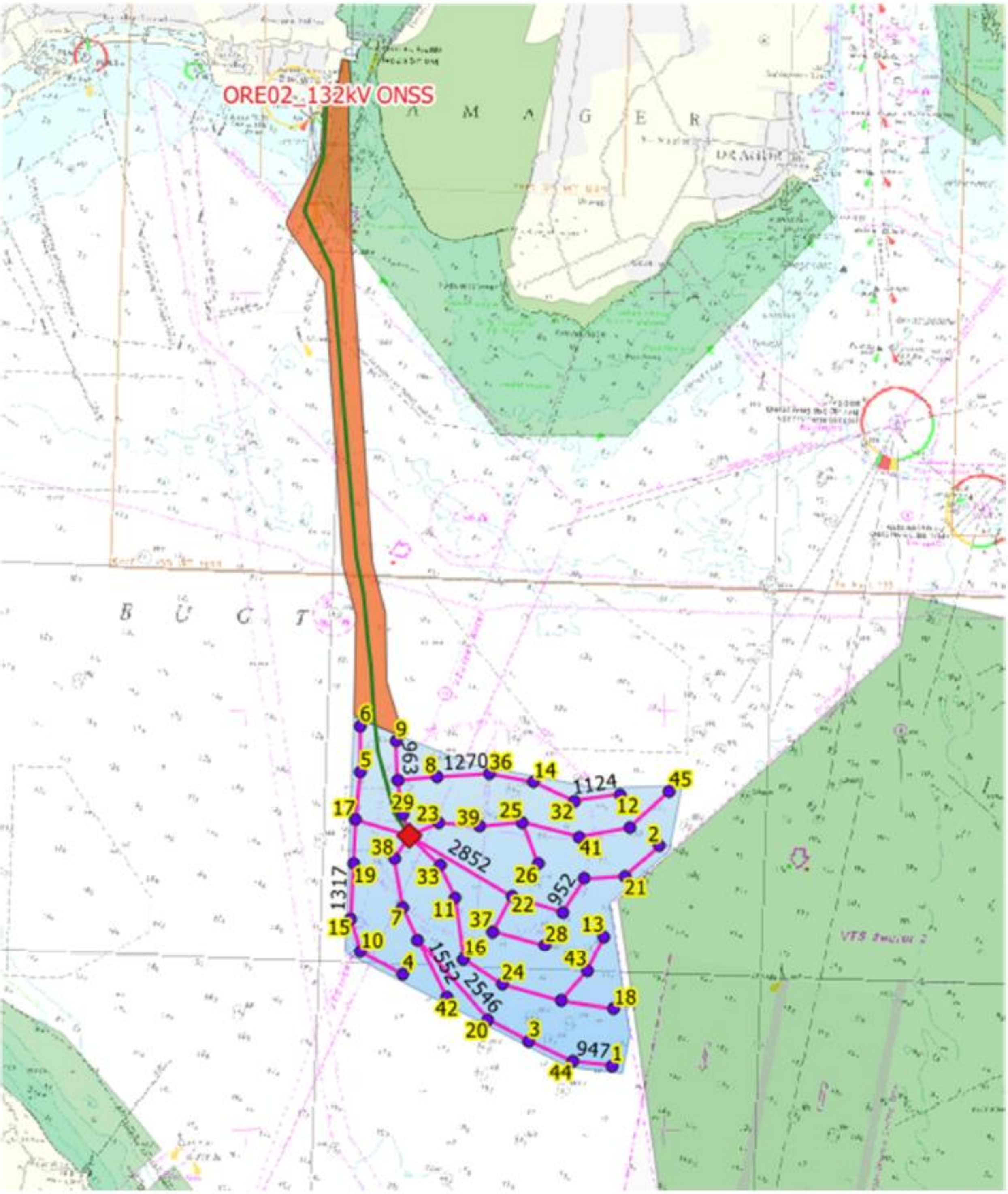
WTG	UTM – ETRS89 zone 32		WTG	UTM – ETRS89 zone 32	
	Easting	Northing		Easting	Northing
1	728297	6144875	14	726377	6151416
2	724053	6147726	15	728093	6151280
3	727151	6145049	16	723952	6150333
4	729515	6151503	17	723352	6151988
5	722207	6147138	18	725430	6150155
6	728280	6147831	19	726043	6145518
7	722153	6148683	20	728293	6149037
8	722003	6152417	21	725899	6147599
9	728485	6146498	22	724177	6148934
10	724911	6151572	23	722090	6150261
11	724764	6146058	24	726608	6148776
12	729263	6150261	25	726999	6149968
13	723486	6146599	26	727018	6146686

Appendix 2: Inter-array cable layouts for 33 or 66 kV cables (small turbines)

A.2.1: Possible cable layout for inter-array cables between the wind turbines at Aflandshage Wind Farm if the 5.5-6.5 MW option and the option for onshore substation is chosen. Export cables are to be connected at each of the westernmost wind turbines of each string.

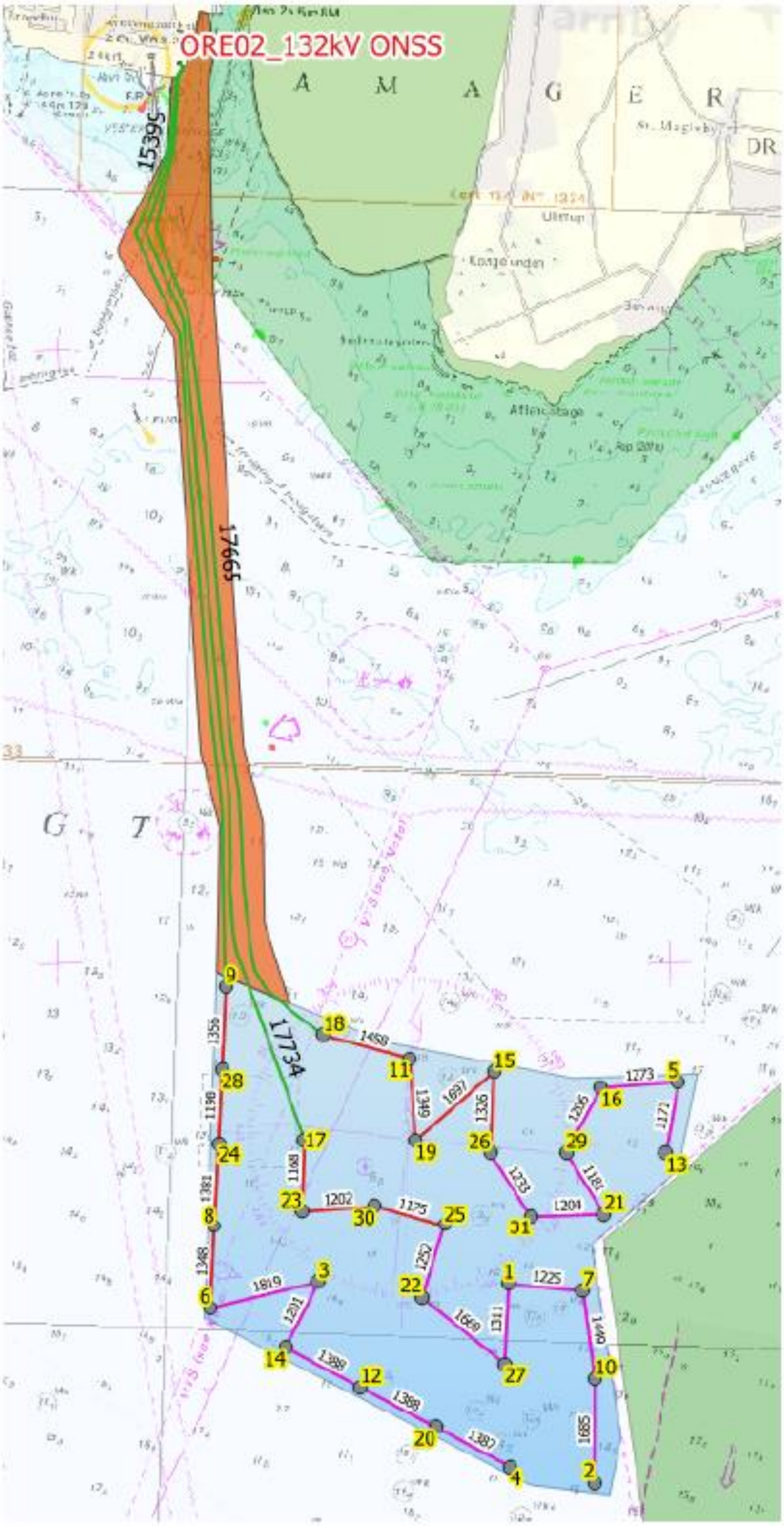


A.2.2: Possible cable layout for inter-array cables between the wind turbines at Aflandshage Wind Farm if the 5.5-6.5 MW option and the option for offshore substation is chosen. Export cables are connected to the offshore transformer station.

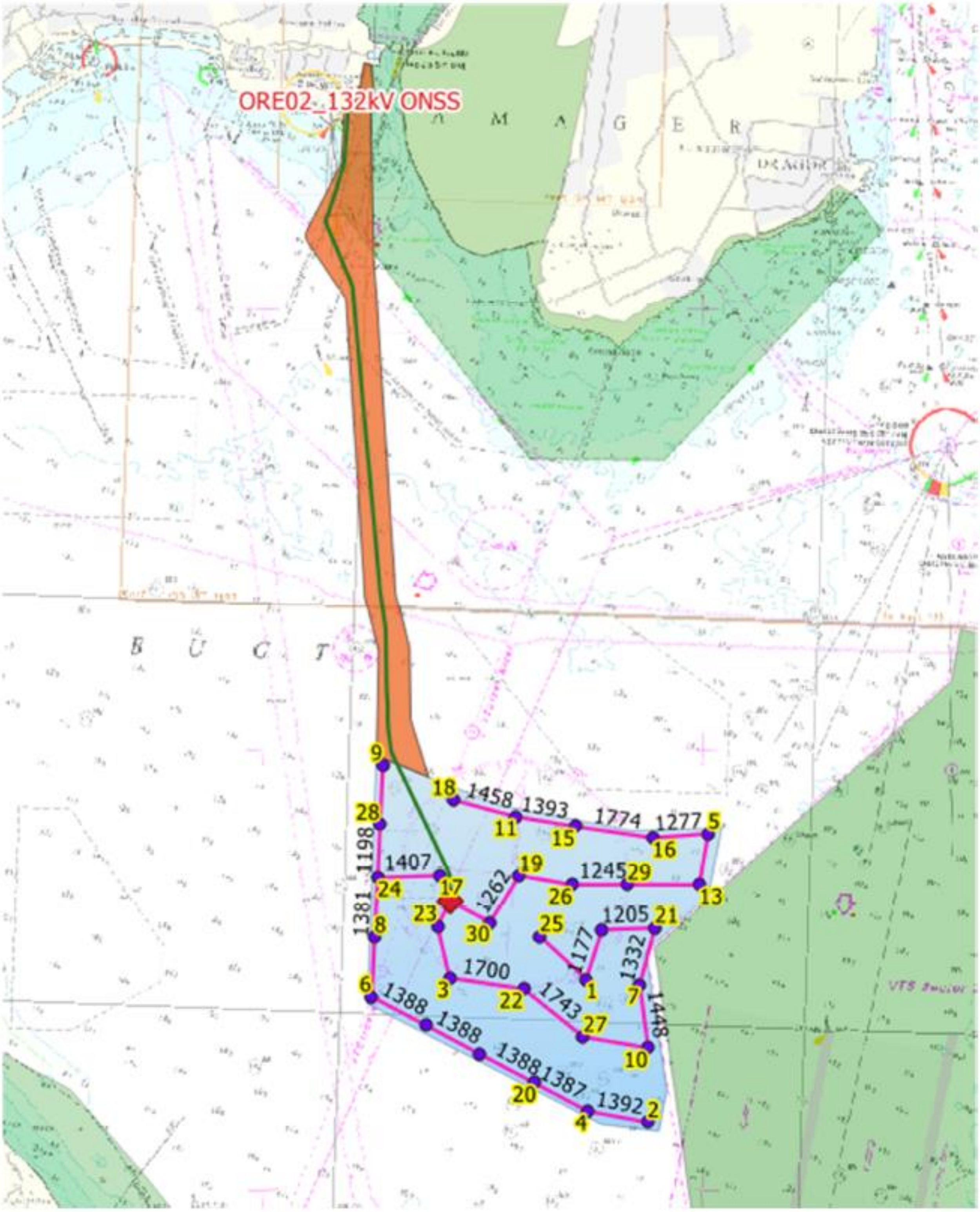


Appendix 3: Inter-array cable layouts for 66 kV cables (intermediate and large turbines)

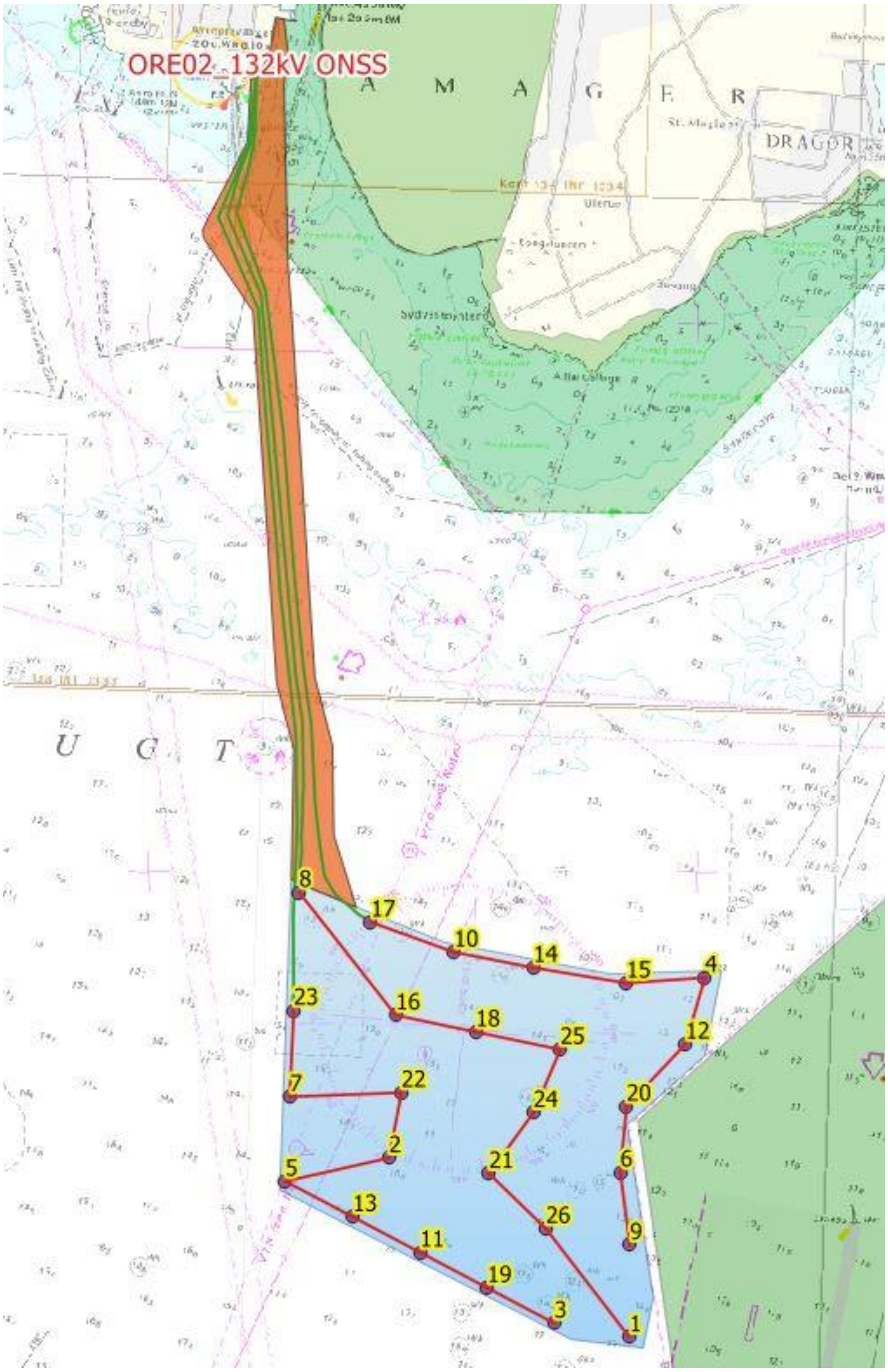
A.3.1: Possible cable layout for inter-array cables between the wind turbines at Aflandshage Wind Farm if the 7.5-8.5 MW option and the option for onshore substation is chosen. Export cables are to be connected at each of the westernmost wind turbines of each string.



A.3.2: Possible cable layout for inter-array cables between the wind turbines at Aflandshage Wind Farm if the 7.5-8.5 MW option and the option for offshore substation is chosen. Export cables are connected to the offshore transformer station.



A.3.1: Possible cable layout for inter-array cables between the wind turbines at Aflandshage Wind Farm if the 9.5-11 MW option and the option for onshore substation is chosen. Export cables are to be connected at each of the westernmost wind turbines of each string.



A.3.2: Possible cable layout for inter-array cables between the wind turbines at Aflandshage Wind Farm if the 9.5-11 MW option and the option for offshore substation is chosen. Export cables are connected to the offshore transformer station.