

**Offshore Wind
Programme Board**

**Overview of the offshore transmission cable
installation process in the UK**

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1 INTRODUCTION AND BACKGROUND

The offshore wind industry has been on a steep learning curve and lessons continue to be learnt from issues encountered on previous projects. Offshore cables are an area where the industry has experienced frequent cost overruns and information from insurance brokers and underwriters indicates that 80% of European offshore wind farm insurance claims have been cable-related¹. **Error! Bookmark not defined.** A clear process and targeted risk management can help to reduce the risks and costs associated with cable installation.

This document describes good practice for the installation of offshore wind transmission cables (export cables) in the UK. It provides an overview of the processes involved in the installation of wind farm subsea export cables.

This document has been drafted by a working group of industry professionals, including developers, consultants, installation contractors, and a number of other related parties. In Autumn 2014, Ofgem held a workshop on key aspects of the OFTO regime. The working group that developed this document was established in late 2014 following on from the regulator's workshop. The working group was tasked with identifying existing good practice in cable installation and producing a high level resource which captured this in one place. The purpose of doing so is to share this good practice with a wider audience in order to de-risk future offshore transmission development and ultimately reduce costs. , The Offshore Wind Programme Board Grid Group² agreed to publish the outputs from this working group in support of its aim to reduce the cost of offshore transmission associated with offshore wind power.

The working group participants brought with them a range of experiences that were discussed in the group and used to inform and shape this document. The report captures good practice and, in some areas, the different approaches that emerged from the group's experience. The group contributed information and collectively reviewed the resulting report, which is presented in the following sections: process map and timeline; surveys for route planning and cable protection; specification and procurement of installation works; installation planning and preparation by developer and contractor; installation methods and execution; and post-installation.

This document will help to enhance communication and coordination of export cable-related activities by providing a common understanding of the cable installation process and by consolidating the results of the learning curve to date. It reflects a typical current process based on experience to date and does not aim to be prescriptive, recognising that individual organisations and projects have variations on this process and that there will be further innovations in the future. Further, this document should not be taken as representing the views of any environmental, permitting or consenting organisation or authority, or interpreted as guidance of what is required to meet any environmental or planning legislation.

¹ The Carbon Trust, 'Cable burial risk assessment methodology - guidance for the preparation of cable burial depth of lowering specification' CTC835, February 2015

² Offshore Wind Programme Board (OWPB) Grid Group. This group is working on areas with the potential to reduce costs in transmission connections.

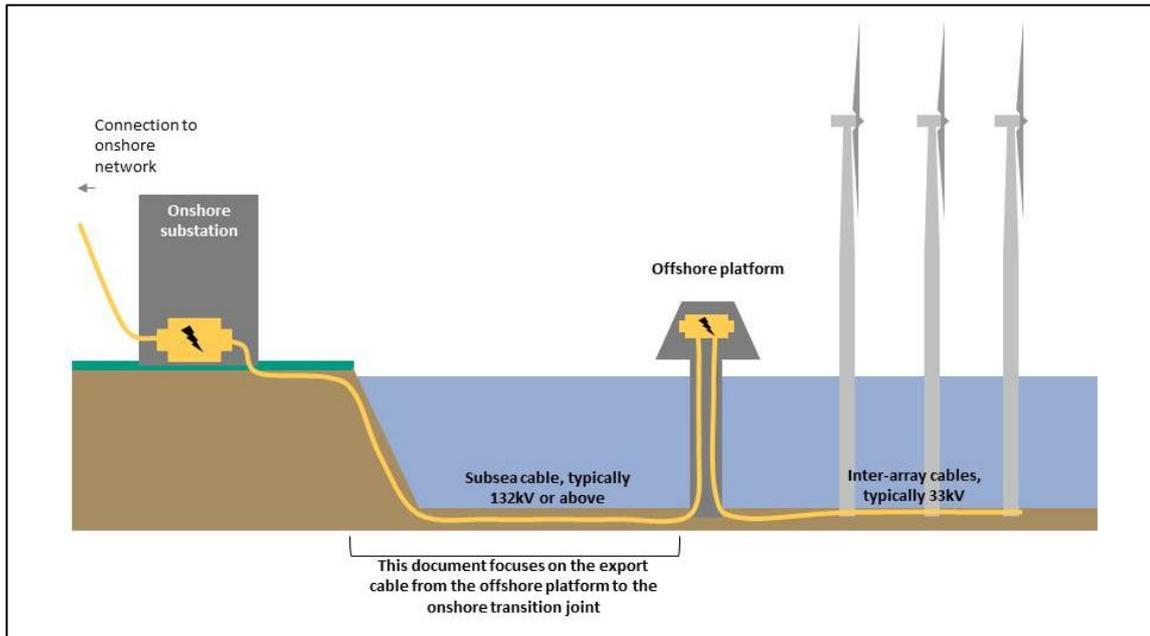


Figure 1 shows the main transmission assets for a typical offshore wind farm. This document focuses on the installation of the subsea transmission cable between the offshore platform and the landfall. Whilst this overview does not extend to inter-array cables or interconnector cables, there are many common areas between these and export cables.

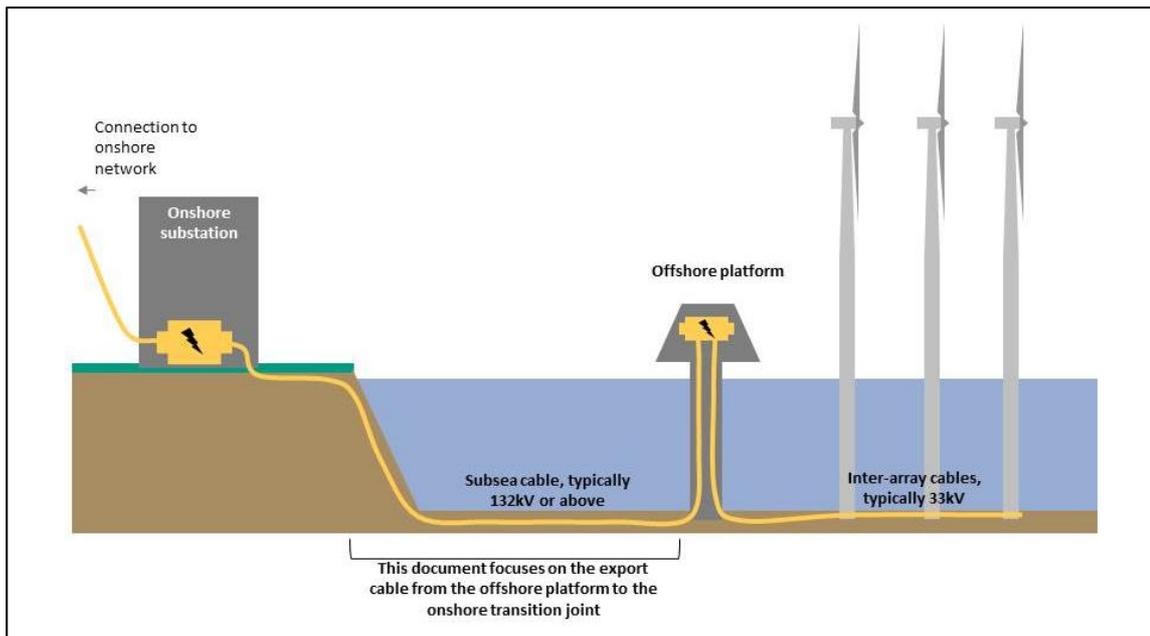


Figure 1: Offshore wind transmission assets for a typical offshore wind farm.

2 PROCESS MAP AND TIMELINE

Table 1 on the following page shows an indicative timeline for developing and installing the transmission cable, up to the point of handover from the developer to the Offshore Transmission Owner (OFTO³). Timings are shown in months, before or after Final

³ In Great Britain, under the regulatory regime's developer-build model, new offshore transmission assets are

Investment Decision (FID). The timeline will vary from project to project, depending on the specific engineering and financial challenges involved. The timing of the FID also varies according to the approach and strategy of each offshore wind farm developer.

The timings given for each stage, although indicative of the approximate start of each step, do not reflect the full complexity of the interfaces affecting each step. The timeline reflects the scenario in which the wind farm developer builds the transmission assets, as has been carried out to date in the UK. In future, projects may have the developer or an OFTO build the assets, which could result in a different approach to that given below.

Table 1 also shows the main stakeholders active during each project stage. Experience of installing offshore wind farms has shown that projects are more likely to be successful if relevant stakeholders are involved as early as possible.

Timeline	Stage of the project	Description	Lead stakeholders		
	Secure the site	Obtain development rights	Crown Estate	Developer	
-48 months	Initial feasibility	Initial engineering/pre-FEED	Developer		
-36 months	Consenting	Start consent process	Planning Inspectorate	Developer	
-36 months		Initial surveys	Survey contractor		
-12 months		Obtain planning consent	Planning Inspectorate	Developer	
-9 months	Tendering	Writing of specification	Developer		
-6 months		Cable installation tendering period	Developer	Contractors	
-3 months		Installation tender evaluation	Developer		
-1 months		Preferred bidder selected	Developer		
0	Securing investment	Financial Investment Decision	Developer	Investors	
+1month	Tendering	Contracts awarded	Developer		
+2 months	Route survey	In depth route engineering/detailed FEED	Developer	Contractors	
+2 months		Further seabed surveys (if required)	Developer	Contractors	
+18 months	Installation and commissioning	Cable installation, burial and jointing	Contractor		
+18 months		Post-installation survey	Contractor		
+20 months		Cable termination	Contractor		
+21 months		Cable testing and energisation	Developer	Contractor	
+36 months	Fully operational	Handover from Developer to OFTO	Ofgem ⁴	Developer	OFTO

Table 1: Wind farm project timeline.

There are three key stage gates to the completion of a project and therefore three points at which the project could stop. The first is the initial engineering which shows, based on desktop studies and widely available information, if the project is feasible.

The second stage is to obtain a development consent order. Due to the involvement of multiple stakeholders, this can be a challenging process, during which the project can be stopped. Ground investigation works (both on and offshore) must be carried out, requiring the developer to invest funds to provide sufficient detail for the tendering stage of the project.

The third and final gate is the Financial Investment Decision (FID). Once the project has received the FID, funds are released for detailed route engineering studies. The transmission assets delivered by the developer will need to be transferred to OFTO ownership at the end of the process.

Appendix C provides a process diagram to illustrate stages in the cable installation decision-making process.

⁴ Ofgem is responsible for managing the competitive tender process through which offshore transmission licences are granted.

3 CONSENTS AND PLANNING

Described here is a high level view of the planning and consenting process required for subsea cable assets on offshore wind projects. The planning and consenting requirements for all elements of the project need to be considered by the developer. These include the wind turbine generators, inter-array cables and substation offshore, as well as the export cables and potentially a substation onshore. However, this section only covers the offshore cable-related aspects.

The duration of the planning and consenting process is therefore determined by the nature of the individual project and it is not possible to treat the subsea cable as an isolated element.

3.1 Consent needed for transmission assets

For offshore projects a national competent authority (NCA) will grant approval for the project. According to the Planning Act 2008, in English waters the NCA is the Marine Management Organisation (MMO) for a project under 100MW. If the project is over 100MW the Secretary of State has the final decision. In Scotland, marine licences are the responsibility of Marine Scotland. The Department of the Environment in Northern Ireland and Natural Resources Wales are the licensing authorities in their respective territories.

Further information on consents can be found in Appendix D.

3.2 Extra permissions

If an activity is taking place in the habitat of a European Protected Species (EPS), an EPS Licence may be required. This Licence may be granted to allow persons to carry out activities that would otherwise be prohibited. Responsibility for issuing an EPS Licence falls to:

- Natural England for onshore projects in England;
- the MMO in the UK marine area;
- the Energy Consents and Deployment Unit (ECDU) for onshore projects in Scotland;
- Marine Scotland Licensing Operation Team (MSLOT) for offshore projects in Scotland;
- the Department of the Environment (DOENI) in Northern Ireland;
- Natural Resources Wales (NRW) in Wales.

3.3 Grid connection agreement

Ofgem will only run a tender for an OFTO if the wind farm has a grid connection agreement with National Grid Electricity Transmission (NGET) PLC (in Great Britain).

In Scotland, the transmission system is run by the National Grid but is owned by two Transmission Owners (TOs): Scottish Hydro Electricity Transmission and ScottishPower Transmission.

To supply to the grid in Northern Ireland, a licence must be obtained from the Northern Ireland Authority for Utility Regulation (NIAUR).

3.4 Statutory consultees

In all consenting regimes, the statutory consultees are likely to include the following:

- Local planning authorities;
- The MMO (where projects have an effect in waters as defined in regulations);
- Environmental organisations (e.g. the Environment Agency, Natural England, the Scottish Environment Protection Agency, the Northern Ireland Environment Agency and National Resources Wales);
- The Health and Safety Executive;
- English Heritage, Scottish Natural Heritage, or Cadw;
- The Joint Nature Conservancy Council;
- Water authorities;
- Landowners or occupiers identified in legislation as having an interest in the land on which the infrastructure is to be constructed.

An additional factor for consideration is that there may also be constraints placed on the timing of construction activities, particularly for near shore works. The constraints may also apply for any subsequent works throughout the OFTO lifespan. Further information can be found on consents for different elements of a wind farm in Appendix D.

4 SURVEYS FOR ROUTE PLANNING AND CABLE PROTECTION

A brief overview of marine surveys for cable route planning and protection is provided below. Further information on surveys is available in the accompanying '*Overview of geophysical and geotechnical marine surveys for offshore wind transmission cables in the UK*'.

4.1 Importance of surveys

Surveys are critical to informing and optimising early planning decisions, the cable route, the installation methodology and tools, the capabilities of the installation vessel and the time required for operations, amongst other things. The information helps to reduce uncertainty and risks to a manageable level.

Installation and burial contractors need survey information to select appropriate cable installation and protection methods. Surveys provide a basis for optimising cable protection using a risk-based approach. The cable protection solution(s) need to be determined during the planning stage, taking into consideration the risk of cable damage and therefore outage of the cable transmission system.

The most common approach to export cable protection is burial, but this is not the only solution. Other approaches may be used to supplement and optimise the level of protection and to reduce the risk to an acceptable level for the owner and the insurer.

Inadequate surveys can lead to the wrong tool being deployed, or failure to bury at the target depth⁵. For these reasons, appropriate marine surveys are an essential factor in the success of a cable installation operation.

Due to the risk of a project not proceeding beyond FID-stage, developers often seek to manage risk by minimising investment in the early project development phase. This limited funding affects investment in the initial surveys. However, past experience of installation issues resulting from unexpected seabed conditions serves to underline the importance of effective and early survey planning.

4.2 Outline of marine surveys undertaken for export cable installation

A comprehensive site investigation is required to collect relevant information about the seabed along the route.

In principle, any site investigation has three phases. Firstly, a desktop study will be conducted to identify the areas of interest and what is required for detailed investigation. A thorough desktop study of the available information will help to target the first phase of the offshore survey.

The desktop study paves the way for a geophysical survey, which obtains data about the surface of the seabed, with some techniques able to provide data on shallow depths of up to 10 metres below the seabed. Geophysical surveys are non-intrusive and consist mainly of bathymetric surveys, side-scan sonar and the use of a sub-bottom profiler to characterise the seabed, its mobility and the shallow geology. It can therefore provide information along the entire route, in contrast to the discrete geotechnical survey locations. However, geophysical information taken in isolation is unable to identify soil types and soil thickness, which require a geotechnical survey.

A geotechnical survey, typically consists of discrete seabed tests undertaken at intervals along the route to validate or 'ground truth'⁶ the geophysical data, which helps to identify seabed type, seabed strength and layer thickness. The geotechnical survey should focus on locations where more challenging seabed types are expected.

There are several methods for obtaining geotechnical information including cone penetration test (CPT), vibrocore, boreholes, grab sampling and box coring. Depending on the chosen method, it may provide data on seabed strength and seabed type. Complementary methods can be used simultaneously, as a single method may not provide all the required information.

Surveys not only provide detailed analysis of seabed conditions, they also help to

⁵ Depth of burial is normally defined as the distance from the seabed level to the top of the cable.

⁶ Ground-truthing is the verification of seabed types.

identify foreign objects on the seabed and potential risks such as the presence of unexploded ordnance (UXO). Surveys will also be required to inform the environmental impact assessment.

The initial desk study should help to identify viable route options and the extent of the marine surveys. When geotechnical and geophysical surveys are performed for a project, both the timing of the survey steps, as well as the type, extent and amount of data collected will shape the installation and protection methodology. The extent of a survey may determine the possibility for later route deviations. The type of survey is important in the context of a complex, heterogeneous soil type, such as glacial till. In areas of moving sand waves there are again implications in planning the timing and extent of a survey.

4.3 Lessons learnt

It is important to involve all stakeholders as early as possible in planning the marine surveys, as the results can impact upon consenting, environmental monitoring and engineering design. It would be useful, if possible, to involve relevant stakeholders, such as cable installation contractors, when planning the marine surveys, to ensure that the information produced is suitable for planning and costing the installation works. In some cases, installation contractors have provided guidelines as to the information they expect from the surveys and the types of surveys recommended. However, key surveys are usually specified before the installation contract is tendered, which means that it is difficult to incorporate the installer's knowledge directly. For this reason, broader industry feedback and lessons learnt should be considered by the developer, from sources such as industry guidelines, subsea cable installation conferences, etc.

Some past projects have seen a disconnect between onshore and offshore surveys, or omitted to survey parts of the near shore and inter-tidal area, which led to difficulties during installation. It is essential that the entire export cable route is surveyed, although the level of detail required along the route may differ.

The industry is moving towards a risk-based approach for cable protection. As a result, the protection requirements may vary along the cable route, as risk exposure and seabed conditions change. This approach will help to reduce cost by ensuring that the required level of protection along the route is appropriate, rather than uniformly applying the level of protection needed at the highest risk point along the whole route. Marine survey information is a key input to a risk-based assessment.

A number of organisations have developed proprietary or published risk-based methods to design burial protection in relation to environmental and third party risks in specific areas (e.g. taking account of the intensity of marine traffic along the proposed cable route). Further information may be found in Appendix B.

5 SPECIFICATION AND PROCUREMENT OF INSTALLATION WORKS

This section describes, at a high level, the strategy and stages of procurement required

to install export cables within the project timeframe for an offshore wind project. Further information is provided in Appendix E .

5.1 Interactions with cable procurement and specification

Cable design will be based on overall electrical system design and will typically be executed during the front-end engineering design (FEED) study phase. Cable design and installation design influence each other.

Cable design characteristics are affected by cable burial depth, soil conditions along the selected route, design of j-tubes at the offshore substation and the landfall construction method. For example, the design of the landfall will determine the thermal conductivity of the cable environment at that point, which could affect the cable cross section required.

Some projects have used a larger cable cross section for the landfall length only. The benefits of this approach are that the larger cable size is not required for the whole length, which may save some cable costs. A drawback is that, with two different cross sections being used for the marine cable, an additional factory or offshore joint will be required. The optimal solution would need to be assessed case by case.

Cable design characteristics will also influence the preferred installation methodology. For example, any margin on the cable rating beyond what is required could increase cable size and therefore the cost of installation by reducing the number of vessels with the necessary capabilities to handle the cable's weight, minimum bending radius, maximum pulling forces, etc. Some projects in the past have taken account of dynamic ratings rather than continuous ratings in their cable specifications, an approach which can reduce the size of cable required to export intermittent wind power. Developers take a range of approaches to this concept.

5.2 Strategy definition/decision

Below is an outline of common contracting strategies:

- Turnkey/engineering, procurement and construction (EPC). A single contractor constructs the whole project to performance specification. Alternatively, a contractor constructs the whole project to a performance specification but a large section, often the civil works, is omitted;
- Multi-contract. The client directly employs a few major, and a large number of supporting, contractors. Pricing strategy is likely to vary to suit the type of contract;
- Construction management. Contractor provides management services but has no responsibility for contract work;
- Management contracting. Similar to above, except the contractor takes on trade specialists as sub-contractors and may take some risk.

Different developers will have different approaches, according to their risk assessment, risk appetite, market factors, etc. For example, EPC arrangements are typically simpler from the developer's point of view and reduce developer risk, but are more expensive

because the contractor has responsibility for delivering more work packages and their interfaces. Multi-contracting is typically more complex from the developer's point of view as it involves a greater degree of management, but the resulting contracts are typically cheaper because the supply chain takes less interface risk.

5.3 Stages of procurement

The supply chain engagement stage is designed to collect sufficient information and carry out research to select the most suitable list of suppliers for the site. A market engagement exercise should be conducted, which will give the project team an opportunity to evaluate the maturity of the supply market and available technology.

The following stage – pre-qualification of suppliers – provides an opportunity for early engagement with the supply market, and a chance to assess new concepts and review previous projects to set benchmarks for the future.

During the tendering phase there needs to be good communications with the shortlisted bidders. A clear scope of work should be produced, with sufficient supporting information for bidders to be able to determine the work required and any associated risks, enabling them to submit a well-costed proposal. All available seabed information should be provided when tendering cable installation works. Relevant parts of the developer business should support the evaluation of the bids.

Each bid should be evaluated against pre-defined weighted criteria. These typically analyse the commercial, technical, health and safety, cost, programme and risk aspects of each submission, giving an overall score for each tender. A report summarises the evaluation process, presents the rationale for each score and draws a conclusion on each bid, before making recommendations based upon the analysis.

Contract negotiations should continue until a detailed project scope is agreed and as much price certainty as possible is achieved. The procurement team will then recommend a contract and seek the legal, financial, risk and FID approvals as required.

6 INSTALLATION PLANNING AND PREPARATION BY DEVELOPER AND CONTRACTOR

The interface between the developer and the contractor is extremely important. These parties must work together throughout the installation process and the parties will need to prepare well to execute the work successfully and to handle any programme delays or operational problems that may arise.

Where possible, the contractor will work with the developer to optimise the cable alignment within the intended corridor and will propose cable burial tools and vessels appropriate to the seabed conditions and required burial depths along the route. The choice of tools will have a direct impact on costs and programme so both the contractor and the developer will be involved in these discussions. The asset lifecycle, including maintenance and repair implications, needs to be considered when designing the installation.

The choice of burial tools, vessels and approach are a vital aspect of the collaboration

between the developer and contractor. Choices are influenced by the amount and quality of the available seabed information. However, due to variations in seabed and soil conditions, and the discrete nature of geotechnical sampling, the information on the seabed conditions should provide a very high level of confidence, but not 100% certainty, about all of the conditions along the cable route.

Another key factor affecting the choice of burial tools is the target cable burial depth. This should be specified using a risk-based methodology. The approach should take into account risks associated with any human activities as well as seabed strength and mobility along the route. Often this results in different minimum burial depths being required for different sections of the cable route.

6.1 Interface management with other parties

Interface management has to be a constant and well-managed process, due to the dynamic nature of any project, and should be considered by the developer when planning the installation. For the developer these interfaces are diverse in nature and include a variety of interactions with companies, for example. between developer and cable supplier; the environment (e.g. weather); any operational restrictions (e.g. from consents or permits); and other physical assets (e.g. the landfall construction and the offshore substation installation).

The cable installation should, in theory, take place after the landfall and offshore substation construction.

Another interface is with the Marine Warranty Surveyor (MWS), who will be involved following the award of the installation contract, or possibly during the tender for the installation contract. The objective of the MWS is to make reasonable endeavours to ensure the risks of the operations under warranty are reduced to an acceptable level, in accordance with best industry practice. As the representative of the insurer, the MWS is a key stakeholder in any project, with the power to stop operations if the risks are considered too high.

The MWS has to understand the programme of work, the operating practices on vessels, and the risks and hazards. They must also understand the weather limitations for various activities. All parties need to review methodologies and documentation and to make sure they resolve any disagreements before the vessel is mobilised. Early dialogue is essential to ensure a smooth process and to allow changes to be implemented.

6.2 Timing

The initial planning by the developer will start at least three years in advance of the cable installation, allowing the project to progress through the various stages of feasibility and financial clearance.

Once the FID is made, which will be 18 months or more before the start of cable installation, then detailed route engineering will be undertaken. Normally, this is the stage when the cable installation contractor becomes involved in the planning, as it will

aid the cable route design process. However, this will often entail only minor alterations to the route, as the cable corridor will have been set in the consenting process.

The contractor will produce a cable protection solution based on the route survey report, including seabed and soil data. Where sufficient information is received, a typical engineering process covering cable installation can be executed over a six month period. This period excludes approval sequences by the developer.

Detailed planning is a collaborative, often iterative, process involving input from both the developer and the contractor. The contractor will develop time schedules informed by their experience. The developer must integrate these time schedules with the overall project programme. The contractor's initial schedule proposal may not fit with the overall programme, which is usually based on connection and first power output of the wind farm and the delivery slot for the power cables. However, the developer's programme preference may result in an installation period that increases the chance of weather delays. For example, a time schedule developed for a July/August window would not work for a January/February window.

Other restrictions that must be factored into the final programme include: tidal ranges (neap and spring tides) and currents, which can limit the windows to commence operations, as neap and spring tides usually vary in a two-week cycle. Additional window restrictions caused by local habitats such as birds and sea-life may also have a significant impact on the methodology, timeline and resources to be used during installation planning. These should also be factored in to the project planning.

Even with excellent planning of the cable installation activity itself, there are a number of related activities that could cause delays. Additional costs have been incurred on some previous construction projects when the plan didn't recognise the risk of delays in activities such as cable manufacture or offshore substation installation. Programme fluctuations become more problematic to manage and more costly the closer they occur to the planned installation date.

Risk analysis techniques and software are available to assess weather risks which can feed into planning. Some export cable installations require several weeks of continuous operations. Severe weather conditions can result in unacceptable risks for the cable laying vessel (CLV) and cable, resulting in delays. Landfall operations are usually very sensitive to weather conditions, which can affect the behaviour of the CLV and the cable to be pulled ashore. The cost of delays can be significant where large vessels are required to standby.

In view of the above, contingency plans and timelines are a critical part of the planning exercise.

6.3 Lessons learnt

Installation planning is often strongly influenced by the requirements of permits and licences. On some past projects these requirements have limited the range of available installation solutions. However, this lesson has been embraced by the industry by

seeking a wider consent scope or 'envelope' to allow for later refinement of the installation design. Also, having experienced parties involved at an early stage in the consenting process enables insights from past projects and feedback from later stages of the process to be incorporated. These approaches to continuous improvement will help to ensure that future consents are more flexible and open to the various cable installation techniques available.

Similarly, feedback should inform the process of route determination for the export cable. Feedback from previous projects has shown that the impact of cables passing through port areas can be complex. If possible, a cable route avoiding port areas is preferred. This is because the increase in marine traffic leads to tighter operational constraints and cable burial depth requirements, which have in the past increased project costs.

Contingency plans to cover critical paths in the installation process should be incorporated into the overall execution plan. This includes not only contingency timelines, as mentioned in the previous section, but also operational contingency plans, such as for cable abandonment and cable repair. Remedial works may be needed where cable protection levels are deemed insufficient. For example, for rock placement or mattress installation work, additional permits and licenses may be required, which will take time to obtain. Contingency measures should also include plans for approvals of necessary changes to the installation methodology as, in the past, projects have needed to make late changes in response to unforeseen seabed conditions or weather changes while the vessel is on-site.

Standard administration procedures for cable installation contracts should be adopted. Document submission and approval sequences should be agreed in advance and implemented to cover the deliverables needed under the installation contract.

Interface management between the main activities, such as foundation installation and cable installation, has improved in recent years. In earlier offshore wind farm developments, cable installation would typically wait until the substation foundations and/or topsides were installed. This occasionally led to delays in the cable installation programme, as a consequence of delays in the construction of the offshore substation. In more recent projects, high level construction programmes allow for decoupling of these two activities, which means the installation of cables can be scheduled during the most suitable period of the year, with the offshore cable wet-stored for periods of four to 12 months, if necessary.

7 INSTALLATION METHODS AND EXECUTION

Installation can commence once the planning, consents approval and procurement and preparation of cable installation works are complete. Below is an overview of the cable installation activities and the main types of solutions employed. More detailed information may be found in the further sources of information listed in Appendix B, in particular the DNV recommended practice document: *'Subsea power cables in shallow water for renewable energy applications'*.

7.1 Overview of the installation process

Typically, cable installation activities start with a pre-lay grapnel run to clear debris from the cable route or an alternative method to check for debris. The export cable will be collected from the load-out port or the cable manufacturer. The installation of export power cables requires a dedicated cable lay vessel (CLV) or barge. The CLV or barge must have a turntable or carousel cable storage facility to load, transport and install these cables. The properties of the specific cable will define cable-handling limits, such as the bend radius limit, which the installers must be aware of when designing the handling and installation methods.

Following transit to the work site, a 'shore pull' will take the cable to the onshore transition joint pit, where it will eventually be jointed to the onshore cable. Typically, this stage involves floating the cable to the shore, using flotation devices and/or rollers at intervals along the cable length. Long distance floating requirements in areas with significant tidal ranges and currents force the installation process to commence with this shore pull, as at London Array shown in Figure 2.

Depending on the landfall site, some projects use horizontal directional drilling (HDD), which may extend to the first short length of burial offshore. Other approaches may use open-cut trenches. If the cable is laid on a beach, it will be buried by a backhoe digger, plough or other specialised equipment.



Figure 2: Illustration of shore pull during cable lay. Image courtesy of VBMS.

The landfall environment and local conditions often determine the necessary CLV specification. Vessel draught at full load can be crucial as this, and the shore depth profile, determine how close the vessel can approach the shore. When long and heavy export cables are used, there is a trade-off between loading the cable in single lengths, which avoids cable joints, and the effect of this weight on the vessel's maximum draught.

In some cases, local conditions will require the vessel to ground near the landfall location, reducing the number of suitable vessels available. The limited water depth requires careful management of the cable catenary⁷ as a short catenary leaves little room for error and could easily result in compromising cable integrity. Assuring the vessel position, by working on an anchor spread in shallow water, will assist in meeting the required laying accuracy without compromising cable integrity.

Following the shore pull the cable will be laid along the predetermined route, which may include pipeline and cable crossings. There are a number of different approaches to the design of these, such as rock dumping or mattresses. The design must consider a number of factors, including risks of secondary scour. A proximity and crossings agreement will typically be made between the existing and prospective infrastructure owners. Draft agreements and guidance notes are available⁸.

There is a trend towards DP2 (high redundancy dynamic positioning) to enable cable laying at a reasonable speed without reducing laying accuracy. Cable handling and monitoring is important during installation as the cable can be damaged if the cable bend radius, strain or other limits are not respected during installation. Monitoring can also help to gather useful data on the cable burial results. For example, ploughs can record depressor depths to provide an indication of the potential cable burial depth.

Typically, water depth will increase along the route and whilst the cable catenary becomes easier to manage, tension in the cable becomes more important. Weather conditions in deeper water, further offshore, are often significantly less favourable than those found near shore and may require a vessel with a keel.

Depending on the length of the cable to be installed, the location of the work site and the installation season, a choice might need to be made between a shallow draft vessel for near shore operations and a vessel with a keel for deep water operations.

Subject to the length and weight of the cable, an offshore joint might be required if the maximum manufacturing length or vessel capacity is exceeded. The location of the joint will need to be carefully chosen, taking into account water depth, corridor width, soil conditions and exposure to wind, swell and waves.

Upon approaching the substation location the cable will be either temporarily set down and wet-stored, in anticipation of substation installation, or directly installed into the substation by the cable lay vessel. In some cases it might be beneficial to the cost or programme to release the main cable lay vessel and to carry out the pull-in into the

⁷ The catenary refers to the cable curve or length that is suspended between two points.

⁸ Oil & Gas UK. 'OPO24 - Pipeline Crossing Agreement - Edition 2 and Proximity Agreement - Edition 1 (2008).

substation using another vessel.

Prior to the start of the pull-in operation, the cable needs to be cut to the right length on board the installation vessel. Sometimes a cable protection system is installed over the cable. The pull-in team on the substation will work in close cooperation with the installation crew on the vessel to release the cable from the vessel and guide it into a substation j-tube or other structure, whilst at all times ensuring the integrity of the cable.

Installation would typically be diverless – using Remote Operated Vehicle (ROV) assistance and/or sonar to monitor operations – but it can involve divers and floats if a smaller vessel is used.

7.2 Cable burial

The export cable protection specifications typically require burial to a certain depth, as informed by a risk assessment. Further sources of information on this subject are available in Appendix B. Additional cover may be required if the cable burial target depth has not been met. This section focuses on cable burial methods.

Cable burial can be divided into two distinct solution types: simultaneous lay and burial (SLB), or post-lay burial. Each method has its advantages and disadvantages. Simultaneous solutions reduce the number of vessels that are mobilised. It can be quicker than post-lay burial and therefore more economical over longer distances. Post-burial de-risks cable installation operations by decoupling cable lay and burial, which can take place at different speeds. Catenary⁹ management is also less critical. However, separating the operations requires cable pickup by the burial tool.

The choice of equipment and cable installation method (shown in Figure 3) is determined by:

- the seabed and environmental conditions envisaged along the cable route;
- the level of certainty of the seabed conditions and associated scope and quality of survey data. (In the case of uncertainty, a more robust burial method might be chosen to reduce the risk of needing later remedial action);
- the depth of burial¹⁰ specified by the developer as a result of a risk assessment;
- permitting requirements – in some cases a project may not be able to use a certain technology due to its effects on the environment.
- the installation method (SLB or separate lay and burial).

⁹ The catenary refers to the section of cable hanging between the seabed and the vessel's cable handling mechanism. This needs to be managed so that the section is neither under excessive tension, which could damage the cable, nor under insufficient tension, which could reduce control over the cable's position.

¹⁰ Depth of burial is normally defined as the distance from the seabed level to the top of the cable.

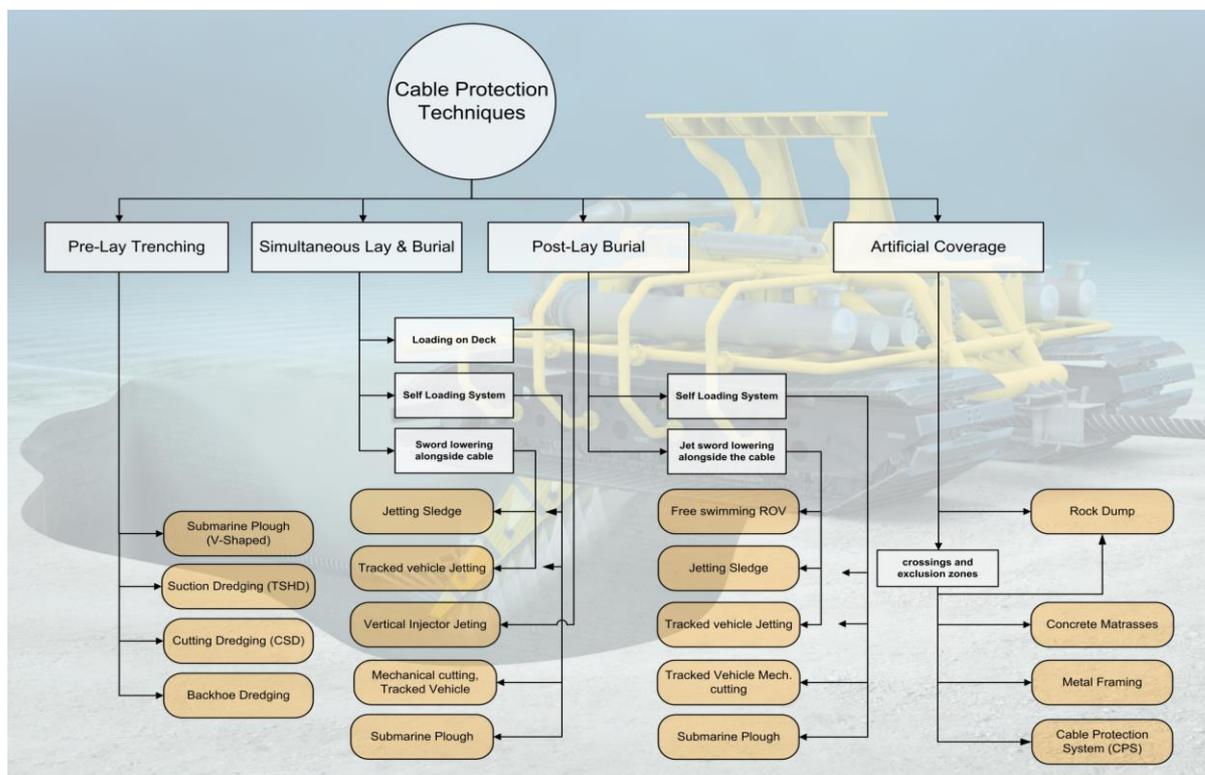


Figure 3: Cable protection technologies. Image courtesy of VBMS.

For an export cable that runs from the beach through the surf zone to an offshore transformer station, cable burial requirements (or any alternative method by which the cable is protected) may change along the cable route. As export cables get longer it becomes more likely that different seabed conditions will be encountered along the route. This means there may be a requirement to use multiple tools to tackle the different seabed conditions and complexities on a particular project.

7.3 Types of equipment

Different cable protection techniques are suited to different project characteristics and matching the right technique to the project is important. The most common tools for burial are described below, along with some advantages and disadvantages of each. However, it should be noted that the choice of tool is generally determined by matching the ability of the tool to achieve the required cable burial depth in the seabed conditions encountered along the route. Some of the advantages and disadvantages noted below may be secondary to this functional requirement.

Ploughs, jet sledges or trenchers and mechanical cutters are outlined below. The key difference is the tool used to cut into the seabed. Greater burial depth requirements reduce the speed of installation for all tools.

7.3.1 Cable ploughs

Ploughs use mechanical force to make a trench. Typically, this is used for SLB with the cable passing through the plough share and emerging between the bottom of the plough share and a depressor. Therefore, the plough makes a trench and depresses the cable into it in one pass.

Cable ploughs of different forms have been used for a long time in the telecommunications industry. They can produce a suitable burial depth in a range of soils. They are predominately used for simultaneous lay and burial, but they can also be used for post-lay burial using a sophisticated grabber and loading system to do this subsea. See Figure 4.

The advantages of a plough are:

- Single pass, where generally cable burial depth equals plough share depth;
- Can be used in a range of soils, from sands to stiff clays;
- Instant cable protection when the cable is laid simultaneously.

The disadvantages of a plough are:

- Cable loading can lead to mechanical damage;
- The high pulling force required to plough through tough soils means that the potential severity of damage to the cable can be greater when using a plough;
- In stiff clays, a higher bollard pull plough and therefore larger vessel is required. Some ploughs can be fitted with jetting pumps, which lessen the bollard pull and act as a fore-cutter to ease the operation;
- They can induce residual tension in the cable, causing wear over time;
- Course changes need to be gradual;
- Ploughs can have difficulties when handling bundled products.



Figure 4: Cable in position on a beach ready to start ploughing. The cable will be pulled from the vessel through the plough and anchored in preparation to start. Image courtesy of VBMS.

7.3.2 Jet sledges and jet trenchers

Jet sledges and jet trenchers are normally used where the seabed material can be fluidised, such as in areas of sand and clays. Jet equipment is normally surface-fed, with water pumps on the barge or vessel, though the more sophisticated systems can have pumps mounted to be used subsea. Surface-fed systems require hoses and umbilicals to run down to the machine. The resultant limitations on handling and water depth

restrict operations to depths of about 30m.

Jet sledges are used for simultaneous lay and burial, see Figure 5. Jet trenchers bury the cable after it has been laid on the seabed. They do not handle or load the cable but sit astride it with aluminium rounded jet legs that deploy into the seabed as shown in Figure 6.

The advantages of jet-based tools are:

- They can offer relatively high burial speeds. Where jetting is suitable for the conditions, the higher speed can offer a cost advantage;
- They minimise the risk of damage to the cable;
- Jet equipment is traditionally used in areas of multiple sand waves, or where an area of sand waves has been pre-swept for the cable to be installed;
- Jet trenchers (but not jet sledges) are used to carry out remedial and multiple passes to achieve burial, whereas ploughs are single pass only. (Remedial burial is then completed by a jet trencher).

The disadvantages of jet-based tools are:

- Their application is limited by seabed conditions, as jetting is not effective on harder soils. However, newer, more powerful machines are increasing the seabed stiffness limits, extending their operational window;
- Jet sledges cannot be used in areas where jetting in the near shore is prohibited.



Figure 5: Typical jet sledge deployed from the beach and used to trench in sands and soft clays. Image courtesy of MODUS Seabed Intervention Limited.



Figure 6: (left) large jet trencher; (right) multi-nozzle jet legs, which are configured and sized relative to the soils to be jetted. Both images courtesy of Helix Canyon Offshore.

7.3.3 Mechanical trenchers

Mechanical trenchers use a wheel or cutting chain to form a trench in which the cable falls or can be depressed. Mechanical trenchers are normally used for high-strength soils and are normally deployed from a support vessel, independent of the lay vessel. The cable is normally loaded into the trencher and the trencher follows the surface-laid cable, burying it as it goes. Alternatively, this equipment may be used for pre-lay cutting. Mechanical trenchers are shown in Figure 7.

The advantages of mechanical trenchers are:

- Mechanical cutters can cut through harder soils, and do not need a high bollard pull vessel to do so.
- While they are slower than a plough, decoupling the lay vessel from the trenching vessel can have a cost advantage;
- The greater the distance offshore, the more likely it is that the project will use direct current (DC) assets. These are bundled and better buried with a post-lay burial machine. A plough can experience difficulties when handling bundled products;

The disadvantages of mechanical trenchers are:

- They generally have to pick up and handle the surface-laid cable, therefore increasing the risk of damage;
- Mechanical trenching is slow, although it may be necessary for certain soil conditions. Cutting speed decreases with greater burial depths, which therefore increases the cost to the project. Optimising depth of burial (DoB) in a cutting operation is therefore crucial.



Figure 7: (left) typical hard ground mechanical trencher, which needs to be heavy (normally more than 40t in water); (right) trench being formed by the cutting chain. Both images courtesy of Helix Canyon Offshore.

7.3.4 Other types of equipment

There are other types of equipment than can be used to complement the burial protection solution, including those described in this section.

The seabed, with numerous surface and sub-surface boulders, may require clearance prior to trenching. It may need pre-cutting, with the cable being laid into the pre-cut trench. Also, short lengths and ends may use a mass flow excavator to target specific areas where a trencher cannot work. An illustration of such tools is shown in Figure 8.



Figure 8: (left) typical mass excavator, most commonly used for cable recovery. Image courtesy of X-subsea; (right) pre-cutting plough that can be used for boulder removal. Image courtesy of Ecosse Subsea Systems.

7.4 Duration

The time required to complete the installation of the export cable depends on:

- Local conditions;
- The number and length of cables to be installed as part of a wind farm development;
- The installation methodology;
- The timing of installation relative to the seasons.

The availability of cables from the supplier also influences timescales. For example, the installation of a single export cable in North Sea conditions such as those found off the

East Anglian coast can be accomplished in 3-4 weeks. Multiple cables may take two summer seasons, according to project plans, weather, permit and licence restrictions. Projects should also give consideration to the increased risk of cable damage during unfavourable weather conditions and the costs of any resulting cable repairs. These can have a significant effect on the completion of the works.

7.5 Lessons learnt

In the past, some of the decisions made during the permit and licensing process have limited the range of installation options available to a project, without the impact of these decisions being fully recognised. As such, it is beneficial to ensure early involvement of the right expertise for cable lay and burial planning as soon as possible.

Contingency planning, to cover critical parts of the installation process, should be incorporated into the overall execution plan. This is also outlined in section 6.3.

Due to the length of most export cables, installation duration is likely to exceed the reliable weather forecast period (typically five days). During the planning phase, the operational and survival limits of the vessel in various weather conditions should be considered and contingency plans put in place for the prospect of having to cut and abandon the cable, should conditions exceed tolerance limits. Contingency planning during planning and engineering is therefore crucial. Together with the Marine Warranty Surveyor and Insurer, limits and approval procedures should be agreed to avoid any uncertainty regarding the process to be followed when issues arise during the operation. This should include cases such as controlled abandonment of the cable and subsea equipment.

Other areas where practice is improving include:

- Timely involvement of experienced personnel and incorporating lessons learnt, for example from the experience to date of installation contractors;
- Timely involvement of an MWS in the approval process;
- Early confirmation of access to beach sites for critical phases of the works;
- The project and contractor should engage with local communities in advance to inform them how the works will be executed and to discuss the effects they may have on their daily lives.

8 POST-INSTALLATION

Post-installation, it is critical that developers ensure that contractors have installed cable systems as per the project specification. They must ensure that contractual obligations have been satisfied and this validation process also forms a major part of the technical due diligence for prospective OFTOs. Therefore, it is essential that developers collate and present post-installation data in a form that provides useful information for OFTOs.

8.1 Electrical testing

Electrical tests after installation are conducted to demonstrate the integrity of the cable system following installation. Responsibility for testing should be specified in the relevant contracts. The tests verify that the cable has not been damaged during handling, shipping or installation. The International Electro-technical Commission (IEC) and the International Council on Large Electric Systems (CIGRÉ) provide various post-installation testing methods – see Appendix B for further sources of information on testing and standards. However, there is no industry agreement on the recommended approach for particular cable types and lengths.

Due to the limited availability of suitable test transformers, it may not be practical to use power frequency testing for high voltage alternating current (HVAC) cables. Therefore, alternative test methods have been developed including:

- Very low frequency (VLF) tests – using frequencies in the range 0.1 Hz to 10 Hz. These are generated using lightweight electronic components to generate a beat frequency, using two superimposed oscillators with slightly different frequencies;
- Resonance tests – where a series test system is tuned to the natural frequency of the cable system (typically 20 – 30 Hz, determined by cable length);
- Soak test – where the cable system is connected to the grid;
- Time domain reflectometry (TDR) – where a low energy, short-rise time pulse is injected along the conductor of the cable, allowing any anomalies to be identified. The resulting data effectively creates a unique ‘fingerprint’ of the cable system. TDR techniques are used to verify the integrity of optical fibres used for communications and distributed temperature sensing (DTS) systems.

Partial discharge (PD) tests can be performed in conjunction with high voltage tests. These can also provide a fingerprint for comparison during all stages of cable manufacture, installation and subsequent in-service operation.

For high voltage DC (HVDC) cables, testing following installation is simpler and less problematic than HVAC cables. Hence the likelihood and consequences of only detecting a defect during final energisation can be minimised.

Post-installation cable testing can provide additional confidence during asset transfer, particularly when problems have arisen during cable installation, which may have caused overstressing of the cables. This is particularly the case if transfer occurs early in the post-energisation life of the cable. For both HVAC and HVDC cables, further confidence that there are no inherent weaknesses in the cable can be best gained post-energisation through current loading cycles of the cables. The ability to perform such loading cycles depends on sufficient wind turbine generation capacity being available.

Projects delivered to date have been completed with and without post-installation cable testing. Best practice is to carry out these tests, helping to confirm that confidence in cable integrity is justified. This is particularly the case where issues have arisen during cable installation.

8.2 Depth of burial (DoB) assessment

After cable installation and before handover to the OFTO, a DoB assessment is required. This should be completed from landfall to the offshore transformer station. Data may be collected from cable installation tools and/or a standalone survey, which is often conducted. This data is used to:

- Verify that the completed installation and protection works have been completed in accordance with the requirements and agreed contract;
- Provide adequate information to the OFTO confirming that the developer's obligations have been met and the risks associated with fulfilment of the OFTO licence can be mitigated;
- Verify that obligations to other stakeholders (e.g. MMO, Port Authorities, The Crown Estate, subsea asset owners) have been met.

The final post-lay survey should be completed after all installation work including lay, burial, crossing and rock placement etc. have been finalised.

The post-lay survey should provide:

- The position of the cable compared to the defined cable route;
- The DoB and/or depth of cover, as applicable to adjacent mean seabed level bathymetry along the cable position;
- Verification that the condition of cable protection is in accordance with the design specification;
- Confirmation that the minimum separation distance and minimum required height of cover at crossings have been achieved and that maximum height of cover is not exceeded;
- A record of length and cross-profiles of the protection and adjacent undisturbed seabed at regular intervals;
- Video or alternative survey method of the covered cable length;
- A check of any existing infrastructure in close vicinity to the cable route, in order to ensure that the infrastructure has not suffered damage;
- The location of any areas with observed seabed mobility, scour or erosion along the cable route;
- Identification and quantification of any free spans, with length and gap height;
- A description of previously unidentified wreckage, debris or other objects which may affect the cable system;
- The location of any damage caused to the cable;
- Video documentation of the subsea cable system interfaces and damage locations etc, if applicable.

DoB surveys are usually performed using industry standard equipment. Each system has its advantages and limitations, especially when the small diameter cables are buried to depths of more than 1.5m.

Before a project starts, the installer or burial contractor will define a suitable system to detect and chart the final DoB of the cable. This system and equipment will need to be appropriate to the type of cable being installed and its depth of burial target.

Evidence from burial equipment recordings during the lay, or post-lay burial activities, can also be included with the data package. This can provide preliminary information for comparison with the final post-lay survey data.

Surveys should be completed soon after the execution of the works, particularly in areas of mobile seabed as seabed level is used as a reference for cable protection.

8.3 Post-burial risk assessment

The pre-installation burial protection assessment will provide a risk-based approach to setting target burial depths. This assessment can be reviewed based on the actual conditions encountered during the installation campaign. For example, the soil strength can be determined from plough telemetry and compared to pre-lay surveys at intervals along the cable route.

On this basis it is possible that minimum burial depths, determined pre-installation, could be revised during a post-installation review of the risk assessment. The post-installation risk assessment methods should be consistent with those of the pre-installation risk assessment.

8.3.1 Remedial works

If the design intent has not been achieved after post-burial survey and a review of the risk assessment, then remedial works will be required. There could be a number of possible causes:

- The weather restricted operations during installation;
- Soil conditions;
- Accident or contractor error;
- Unforeseen obstacles.

Remedial works may include:

- Post-lay trenching – this may be restricted to jetting where the cable is partially buried and cannot be loaded into a plough or mechanical trencher. Mechanical trenchers may be used if the cable is on the seabed or buried to a very shallow depth. Caution should be applied though, as the stress induced during the loading and unloading process can damage the cable;

- Additional rock placement – in such circumstances, the grading, composition, positioning and deployment of rock material needs to be carefully selected;
- Installation of mattresses – these must be selected in terms of size, shape and flexibility;
- Rock material within rock filter bags – this has to be selected in the same way as rock placement. Additional consideration must be given to the performance of the bag material and the consequential impact upon decommissioning.

All of the factors considered during the cable protection risk assessment have to be taken into account during the selection of remedial work.

It will be necessary to measure and demonstrate that the design intent of the remedial works has been achieved, generally through additional survey work.

Consideration of the requirements of the OFTO at this stage is essential in order to ensure a smooth handover. Technical due diligence will often focus on remedial works where the minimum burial depth was not initially achieved.

Furthermore, it is important to remember that remedial work is likely to be subject to a separate Marine Licence.

8.4 Information handover

To achieve successful cable installation and asset handover to an OFTO, it is essential that documents, reports and electronic files are made available, which are timely, appropriate and accessible. A list of key documents can be found in Appendix F.

A comprehensive document register, with all necessary documents to allow the above process to be validated, is essential. This not only confirms the completion of the installation contract to the satisfaction of the developer and contractor, but also for this to be subsequently demonstrated to the OFTO, lenders and insurers.

If aspects of the design intent have not been achieved at any stage, then additional documents, such as revised risk assessments, need to be produced to demonstrate that the design achieved still meets the project requirements.

Inconsistencies between the stages of the project, and document inadequacies, generally cause the most difficulties during the OFTO transfer process. OFTOs play a central role in this process, as the assets delivered by the developer will be transferred to OFTO ownership at the end of the process. The information transferred during asset transfer is the basis on which the OFTO will monitor and plan maintenance on the asset throughout its operational life.

Appendix A – Glossary

Initials	Definition
CIGRÉ	International Council on Large Electric Systems
CLV	Cable Lay Vessel
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
DETI	Department of Enterprise, Trade and Investment
DoB	Depth of Burial
DOENI	Department of the Environment Northern Ireland
DTS	Distributed Temperature Sensing
EA89	Electricity Act 1989
ECDU	Energy Consents and Deployment Unit
EIA	Environmental Impact Assessment
EPC	Engineering, Procurement and Construction
EPS	European Protected Species
FID	Final Investment Decision
HDD	Horizontal Directional Drilling
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
LPA	Local Planning Authority
M(S)A10	Marine (Scotland) Act 2010
MCAA09	Marine and Coastal Access Act 2009
ML(W)13	Marine Licensing (Delegation of Functions) (Wales) Order 2013
MMO	Marine Management Organisation
MSLOT	Marine Scotland Licensing Operation Team
MWS	Marine Warranty Surveyor
NCA	National Competent Authority
NGET	National Grid Electricity Transmission plc
NIEA	Northern Ireland Environment Agency
NRW	Natural Resources Wales
NSIP	Nationally Significant Infrastructure Projects
OFTO	Offshore Transmission Owner
PA 2008	Planning Act 2008 (as amended)
PD	Partial Discharge
PINS	Planning Inspectorate
TCP(S)A97	Town and Country Planning (Scotland) Act 1997
TCPA90	Town and Country Planning Act 1990
TDR	Time Domain Reflectometry
VLF	Very Low Frequency

Appendix B – Sources of further information

BERR (now BIS), *'Review of cabling techniques and environmental effects applicable to the offshore wind farm industry'*, 2008

Bureau of Ocean Energy Management, Regulation and Enforcement – United States Department of the Interior, *'Offshore electrical cable burial for wind farms: state of the art, standards and guidance and acceptable burial depths, separation distances and sand wave effect'*, 2011

The Carbon Trust, *'Cable burial risk assessment methodology - guidance for the preparation of cable burial depth of lowering specification'*, CTC835, 2015

CIGRÉ, Technical Brochures:

'Technical Brochure 194: Construction, laying and installation techniques for extruded and self-contained fluid filled cable systems', 2001

'Technical Brochure 379: Update of service experience of HV underground and submarine cable systems', 2009

'Technical Brochure 398: Third-party damage to underground and submarine cables', 2009

'Technical Brochure 415: Test procedures for HV transition joints for rated voltages 30 kV ($U_m = 36$ kV) up to 500 kV ($U_m = 550$ kV)', 2010

'Technical Brochure 483: Guidelines for the design and construction of AC offshore substations for wind power plants', 2011

'Technical Brochure 490: Recommendations for testing of long AC submarine cables with extruded insulation for system voltage above 30 (36) to 500 (550) kV', 2012

'Technical Brochure 496: Recommendations for testing DC extruded cable systems for power transmission at a rated voltage up to 500 kV', 2012

'Technical Brochure 610: Offshore generation cable connections', 2015

'Technical Brochure 623: Recommendations for Mechanical Testing of Submarine Cables', 2015

DNV, *'Recommended practice: Interference between trawl gear and pipelines [DNV-RP-F111]'*, 2010

DNV-GL, *'Sharing lessons learned and good practice in offshore transmission: A report for The Crown Estate'*, 2014

DNV-GL, *'Subsea power cables in shallow water for renewable energy applications [DNV-RP-J301]'*, 2014

Hoshina, R and Featherstone, J, *'Improvements in submarine cable system protection'*, 2001

International Cable Protection Committee (ICPC) Recommendations:

'Recommendation 1: Recovery of out of service cables'

'Recommendation 2: Cable routing and reporting criteria'

'Recommendation 3: Telecommunications cable and oil pipeline/power cables'

crossing criteria'

'Recommendation 4: Coordination procedures for repair operations near in-service cable systems'

'Recommendation 6: Actions for effective cable protection (post-installation)'

'Recommendation 7: Offshore civil engineering work in the vicinity of active submarine cable systems'

'Recommendation 8: Procedure to be followed whilst offshore seismic survey work is undertaken in the vicinity of active submarine cable systems'

'Recommendation 13: The proximity of offshore renewable wind energy installations and submarine cable infrastructure in national waters'

Recommendation 14: Basic power safety procedures that are to be followed by marine repair operators and terminal station personnel during subsea cable repair activities'

'Recommendation 15: Procedure to be followed whilst marine aggregate extraction, dredging or mining is undertaken in the vicinity of active submarine cable systems'

International Electro-technical Commission:

'60840 Edition 4: Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) – Test methods and requirements', 2011

'62067 Edition 2: Power cables with extruded insulation and their accessories for rated voltages above 150 kV (Um = 170 kV) up to 500 kV (Um = 550 kV) – Test methods and requirements', 2011

Offshore site investigation and geotechnical committee, *'Guidance notes for the planning and execution of a geophysics and geotechnical ground investigation for offshore renewable energy developments', 2014*

OSPAR Commission, *'Guidelines on best environmental practice (BEP) in cable laying and operation', 2012*

Scottish and Southern Energy, *'Procedure for subsea cable route selection', (2004)*

Subsea Cables UK:

'Guideline number 6: The proximity of offshore renewable energy installations and submarine cable infrastructure in UK waters', 2012

'Guideline number 8: Submarine cable decommissioning,' 2012

The Crown Estate:

'Export transmission cables for offshore renewable installations – Principles of cable routing and spacing', 2012

'Export transmission cables for offshore renewable installations: Guideline for leasing of export cable routes/corridors', 2012

'Submarine cables and offshore renewable energy installations proximity study', 2012

The Geneva Convention on the continental shelf, 1958

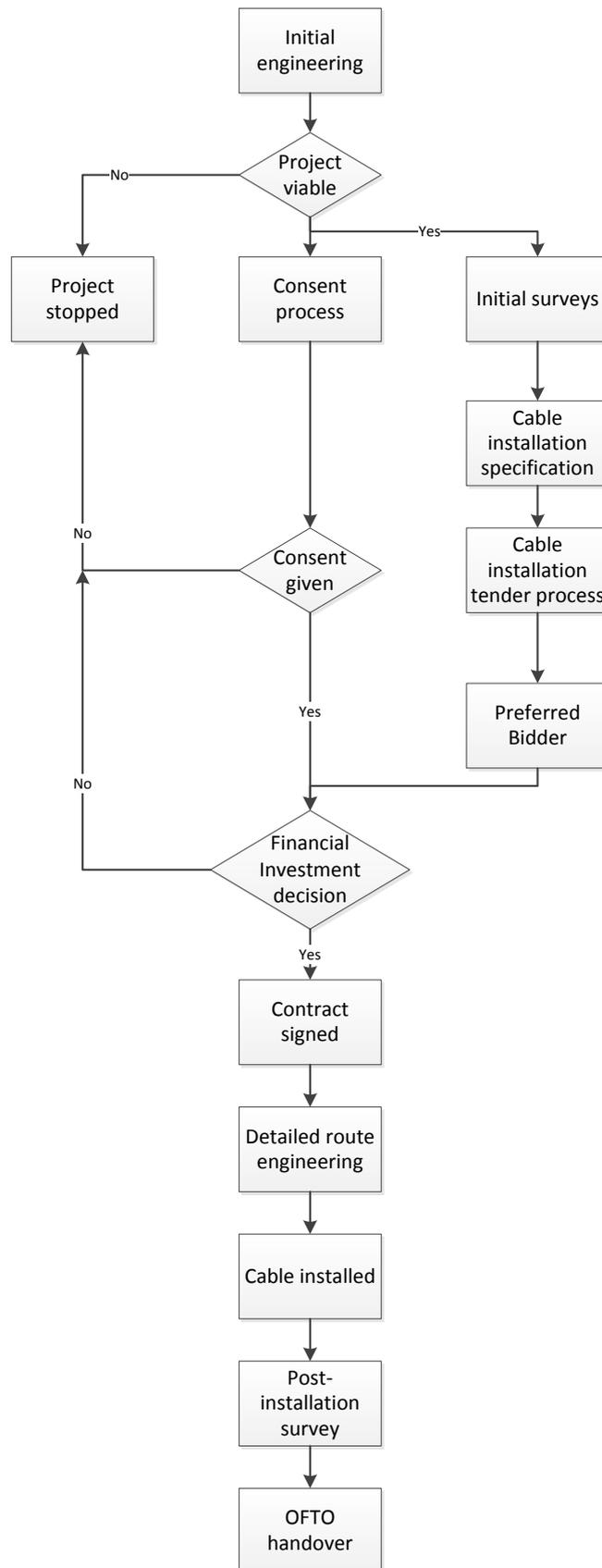
The Geneva Convention on the high seas, 1958

The United Nations convention on the law of the sea, 1982

United States Department of the Interior, *'Guidelines for providing geological and geophysical, hazards, and archaeological information pursuant to 30 CFR part 285'*, 2011

VdS, *'International guideline on the risk management of offshore wind farms: Offshore code of practice'*, 2014

Appendix C – Cable installation process diagram



Appendix D – Further information on consents

England

The Planning Act 2008 as amended (PA 2008) established that nationally significant infrastructure projects (NSIPs) require development consent in the form of an Order, referred to as a Development Consent Order (DCO), granted by the relevant Secretary of State for applications in England. For projects over 100MW the NCA is the Secretary of State, for projects under 100MW it is the Marine Management Organisation (MMO).

Additionally:

To install submarine cables at a distance of up to 12nm, a marine licence must be granted by the MMO using the legislation of Marine and Coastal Access Act 2009 (MCAA09).

Consents for onshore installations is handled by the relevant Local Planning Authority (LPA) using the legislation Town and Country Planning Act 1990 (TCPA90). Onshore installations may also be included in a DCO and TCPA90 consent deemed under MCAA09 or PA 2008.

Underground cables have permitted development rights in most cases. If the underground cable is considered detrimental to the environment an EIA has to be produced and approval is then needed by the relevant Local Planning Authority (LPA) using the Town and Country Planning Act 1990 (TCPA90).

Consents for overhead lines (OHL) grid connections $\geq 132\text{kV}$ $\geq 2\text{km}$ are handled by the Planning Inspectorate (PINS) using the Planning Act 2008 (PA 2008).

Consents for OHL grid connections $< 132\text{kV}$ $< 2\text{km}$ are handled by the Secretary of State and DECC using the Electricity Act 1989 (EA89).

Scotland

Marine Scotland and its Marine Scotland Licensing Operation Team (MSLOT) regulate licensing and consenting schemes on behalf of Scottish Ministers within Scottish Waters (0-12nm and 12-200nm). MSLOT is the single point of contact responsible for the assessment of applications (ensuring compliance with all relevant legislation) for marine licences.

Additionally:

Consents for the installation of submarine cables is handled by Marine Scotland using the legislation of Marine (Scotland) Act 2010 (M(S)A10).

Consents for onshore installations is handled by the relevant Local Planning Authority (LPA) using the legislation, Town and Country Planning (Scotland) Act 1997 (TCP(S)97).

Underground cables have permitted development rights in most cases. If the underground cable is considered detrimental to the environment an EIA has to be produced and approval is then needed by the relevant Local Planning Authority (LPA)

using the Town and Country Planning (Scotland) Act 1997 (TCP(S)97).

Consents for OHL grid connections are handled by the Scottish Minister Energy Consents and Deployment Unit (ECDU) using the EA89 legislation.

Wales

The Welsh Ministers are the licensing authority for Welsh inshore waters (out to 12 nautical miles). Welsh Ministers have delegated licensing to Natural Resources Wales under the Marine Licensing (Delegation of Functions) (Wales) Order 2013.

Additionally:

Consents for the installation of submarine cables is handled by Marine Management Organisation and Natural Resources Wales (NRW) using the legislations Marine Licensing (Delegation of Functions) (Wales) Order 2013) (ML(W)13) and MCAA09 respectively.

Consents for onshore installations are handled by the relevant Local Planning Authority (LPA) using the legislation Town and Country Planning Act 1990 (TCPA90).

Underground cables have permitted development rights in most cases. If the underground cable is considered detrimental to the environment an EIA has to be produced and approval is then needed by the relevant Local Planning Authority (LPA) using the Town and Country Planning Act 1990 (TCPA90).

Consents for OHL grid connections $\geq 132\text{kv}$ $\geq 2\text{km}$ are handled by the Planning Inspectorate (PINS) using the Planning Act 2008 (PA 2008).

Consents for OHL grid connections $< 132\text{kv}$ $< 2\text{km}$ are handled by the Secretary of State and DECC using the Electricity Act 1989 (EA89).

Northern Ireland

In Northern Ireland marine licensing and consenting is carried out under the Marine and Coastal Access Act 2009 by the Department of Energy's Marine Division, Marine Licensing Team. The DoE Marine Licensing Team is responsible for assessing applications and issuing all relevant consents and permissions under Part 4 of the Marine and Coastal Access Act 2009 within Northern Ireland territorial waters (12nm). Consent under Article 39 of the Electricity Order from the Department of Enterprise and Investment (DETI) is required for the construction and operation of any electricity generating station in NI.

Additionally:

Consents for the installation of submarine cables is handled by Marine Management Organisation, Department of Environment (DOENI) and NI Environment Agency (NIEA) using the legislations MCA09.

Consents for onshore installations are handled by the DOENI and the Department of Enterprise Trade and Investment (DETI) under the legislations Electricity (NI) Order 1991 and Planning (NI) Order 1992 respectively.

Consents for OHL grid connections are handled by the DOENI and DETINI under the legislations, Electricity (NI) Order 1991 and Planning (NI) Order 1992 respectively.

Underground cables have permitted development rights in most cases. If the underground cable is considered detrimental to the environment an EIA has to be produced and approval is then needed by DOENI and DETINI under the Electricity (NI) Order 1991 and Planning (NI) Order 1992 respectively.

A summary of the consenting authorities for export cables in the UK is shown in the table below.

Country	Component	Consenting Authority	Legislation
England	Submarine Cables (Export Cable)	MMO	Marine and Coastal Access Act 2009 (MCAA09)
Scotland	Submarine Cables (Export Cable)	Marine Scotland	Marine (Scotland) Act 2010 (M(S)A10)
Wales	Submarine Cables (Export Cable)	Natural Resources Wales & MMO	Marine Licensing (Delegation of Functions) (Wales) Order 2013 (ML(W)13) and MCAA09 respectively
Northern Ireland	Submarine Cables (Export Cable)	MMO, Department of Environment (DOENI) and NI Environment Agency (NIEA)	MCAA09

Table 2: Consenting authorities for export cable installation.

Appendix E – Specification and procurement

This appendix outlines high level procurement objectives, steps and assessment methods.

High level objectives

- Put strategies in place across the different work packages to ensure that they are aligned with the overall programme considered (interface management);
- Establish robust delivery options for projects to meet their expected delivery profiles;
- Provide commercially robust and attractive terms and conditions for tendering of all plant and equipment necessary to deliver the projects' programmes;
- Carry out the tendering of each project overseen by the project manager appointed for the appropriate project/work package;
- Work with industry to ensure that the manufacturing, construction, operation and maintenance of wind farms maintain high standards in relation to health, safety and environment;
- Continuously reduce the Levelised Cost of Energy (LCOE) of offshore wind;
- Optimise design and supply options;
- Achieve a high level of price certainty;
- Achieve the best possible price overall;
- Have fully negotiated and agreed conditions of contract;
- Have all technical schedules developed and agreed, subject to detailed design;
- Agree the risk profile with the preferred supplier, balancing cost-exposure;
- The tender is based upon the need to enter into a collaborative working partnership in order to deliver the cables, ancillaries and installation services in the most cost effective and safe working manner.

Process steps

- Initial market analysis;
- Market engagement with suppliers;
- Preparation of market reports;
- Review with relevant package /project management.

Define and agree strategy

- Define the type and number of contracts required (EPC/multi-contract etc.);
- Risk assessment and justification;
- Identification of resources to implement the defined strategy;

- Review with purchasing and project management.

Draft process contracts

- Draft Heads of Terms;
- Establish and define requirements;
- Discuss non-disclosure agreements and intellectual property rights exposure;
- Scope definition (needs input of other initial works contracts such as the initial seabed surveys);
- Lessons learnt review from previous projects.

Pre-qualification of suppliers

- Begin technical scope definition;
- Start definition of and evaluation methodology;
- Agree timeline for Request for Quotation (RFQ);
- Advise suppliers of the down selection process;
- Improve scope definition;
- Issue the Pre-Qualification Questionnaire (PQQ).

Tendering and bid evaluation

- Increased definition of technical scope;
- Increased definition of evaluation methodology;
- Developer to communicate which documents and technical information are required to be included in contractors' bids;
- Update timeline for RFQ;
- Calculate insurance and liquidated damages requirements;
- Establish Parent Company Guarantee (PCG) requirements;
- Define payment milestones;
- Bonding requirements;
- Defect liability period tables;
- Shortlisting. Process to reduce the number of bidders till Best and Final Offer (BAFO);
- Bid evaluation;
- Negotiation of commercial schedules and Conditions of Contract;
- Pre-contract audits.

Contract approval

- Finalise commercial schedules;
- Finalise conditions of contract;
- Approval for Financial Investment Decision (FID) from project;
- Legal approval;
- Financial approval;
- Risk approval;
- Handover management of the package/project to construction and post-contract management team.

Construction, variation, claims management

- Pre-construction audits;
- Confirm milestones reached as per contract to trigger payments;
- Variations – written instruction from the developer to the contractor for works in addition to the contract scope;
- Claims management – Contractor believes they have incurred extra costs in addition to the sum quoted, which is not under their remit in the contract.

Method of assessment

1. Tenders are assessed

- To financially weigh any offer that does not comply exactly with the specified technical and commercial requirements;
- To evaluate possible risks;
- To decide the most economically advantageous tender on the basis of criteria noted below.

2. Assessment criteria (not in any particular order of precedence)

- Health and safety policy, procedures and resource;
- Tendered prices and rates;
- Compliance with commercial requirements;
- Provision of commercial and performance warranties;
- Quality of resource, experience and CVs;
- Programme and delivery times, including availability;
- Proven track record of product being offered;
- Operability and maintainability of product;
- Design methodology including preliminary basis of design;
- Tenderer's quality assurance and quality management systems;

Overview of the offshore transmission cable installation process in the UK

- Environmental management and performance;
- Project management (resource, process and procedures);
- Optimisation of design, subject to project constraints.

Appendix F – Documents for cable handover process

In order to achieve successful cable installation and asset handover to an OFTO it is essential that information in the form of documents, reports and electronic files be made available. These must be timely, appropriate and accessible.

An example of the types of documentation relevant to cable installation that are typically requested by the OFTO is shown below. Further information on surveys is available in the accompanying ‘*Overview of geophysical and geotechnical marine surveys for offshore wind transmission cables in the UK*’.

Document	Produced By	Stage of Process	Required By
Design basis and functional specifications	Developer	Prior to design	Cable contractor OFTO
Initial survey data	Developer	Prior to contract	Contractor
Design calculations, reports, drawings	Cable contractor	Prior to cable manufacture	Developer OFTO
Manufacturers cable specifications and cable handling guidelines	Cable contractor	Prior to installation	Developer Contractor OFTO
Cable protection risk assessment	Developer	Prior to installation	Developer Contractor OFTO
Prequalification/trial reports	Contractor	Prior to cable manufacture	Developer OFTO
Supply contract	Developer/Contractor	Prior to manufacture	Developer Contractor OFTO
Manufacturing quality and test plans	Contractor	Prior to manufacture	Developer OFTO
As-manufactured documentation and test reports	Contractor	Prior to installation	Developer OFTO
Pre-installation survey	Contractor	Prior to installation	Developer Contractor

			OFTO
Installation plan and method statements	Contractor	Prior to installation	Developer Contractor OFTO
As-built documentation and test reports, including all installation records and DoB assessment, (including MWS report)	Contractor	Post installation	Developer OFTO
Documentation register and all documents	Developer	Pre-transfer	OFTO