ESCA Guideline No.14

Power Cable Installation Guidelines

Document Revision Procedure:

Any party wishing to propose a change to this document should address the proposed change to the Chair of the RPSG of the EUROPEAN SUBSEA CABLES ASSOCIATION. The RPSG will then review the proposed change and consider re-convening a Technical Working Group ("TWG") to discuss the proposal. Once the RPSG (and TWG, if appropriate) are satisfied, their findings and the revised document will be presented to the EUROPEAN SUBSEA CABLES ASSOCIATION Executive Committee and Plenary for approval. Only when all parties have approved the changes will the document be re-issued.

Document History

Issue No.	Name	Comments	Date
1		Initial Issue	Mar 2015
2		Re-branding to ESCA	Mar 2016

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Definitions and abbreviations

The EUROPEAN SUBSEA CABLES ASSOCIATION is presently compiling a comprehensive document that pulls together all definitions and abbreviations that are commonly used in this sector. Please refer to EUROPEAN SUBSEA CABLES ASSOCIATION Guideline 20.

Executive Summary

This document (referred to as the "Guideline") provides guidance on the considerations that should be given by all entities that have a requirement to install subsea power cables. This guideline being particularly focussed on the requirements to install subsea power cables including loadout and transportation as required. This document is not intended to be prescriptive or replace good, comprehensive procedures.

This guideline has been compiled by a very knowledgeable team from within the EUROPEAN SUBSEA CABLES ASSOCIATION. The combined experience of subsea cables that the team and the EUROPEAN SUBSEA CABLES ASSOCIATION bring to this document, has been accumulated over many hundreds of years and many tens of thousands of kilometres of all types of subsea cables installed. These EUROPEAN SUBSEA CABLES ASSOCIATION members have freely given their time and experience in the compilation of this guideline for the benefit of all concerned with the subsea power cable industry.

Scope of the Guideline

The scope of the guideline is focussed on the following eight separate areas:

- Providing an outline of the sequence of operations that should be considered before the actual installation takes place
- Route engineering and Route Position Lists
- Quality control of the cable as manufactured, supplied, installed and commissioned
- Different installation methodologies that can be expected for different conditions
- Vessel expectations
- Equipment expectations
- Scheduled and non-scheduled jointing onboard and joint deployment
- Strategic planning and repairing subsea power cables

This guideline will discuss each of the discreet areas above. There are often many different ways to execute an installation. The selection of an optimum solution is often down to the prevailing conditions expected on site. It should be appreciated also that the prevailing site conditions often vary and as such, the optimum installation solution might not be a single technique but could vary across the whole project site.

Introduction

These guidelines are composed from the perspective of a prospective cable owner / developer who is seeking to implement the construction of a power cable project. It is envisaged that this project could sit within the renewable energy sector or the interconnector sector. It is intended to highlight the processes that need to be adopted in order to allow the cable owner and installation contractor, to arrive at an optimised installation solution and is not intended to be a substitute for the engagement of competent contractors.

In routing, specifying and installing subsea power cables, there is a clear desire to achieve a secure, technically feasible and economically viable route and installation. Subsea cable installation is considered by most authorities on the subject to be benign and an optimised installation will minimise impact on the seabed. Such impacts being transient in nature and short lived.

These Guidelines are intended to cover the following cable types, all of which will have different criteria for successful installation:

- Export cables (AC) used for the export of power from an offshore renewable energy project usually up to distances of approximately 100km from the landing point
- Export Cables (DC) used for the export of power from a renewable energy project for longer distances (the selection balance between DC and AC cable selection is generally a technical / commercial issue)
- In-Field Array or Collector cables usually of 11kV / 33kV / 66kV, used for collection of power from the individual renewable energy devices and routing these back to an offshore substation platform.
- DC Interconnector cables
- AC Interconnector cables
- AC Distribution cables
- AC or DC Transmission cables
- Inter-island power cables

A key component of the design of anything other than a small renewable energy project is the offshore substation platform. This will provide a central point to the architecture of the renewable energy project and houses the transformers and other equipment which convert from the infield voltage to the export voltage. This should be considered as part of the system design of an offshore cable installation and is covered by draft guidance issued by CIGRE.

The primary document for AC systems being “Guidelines for the Design and Construction of AC Offshore Substations for Wind Power Plants” CIGRE 483.

1 TYPICAL LIST OF KEY TASKS:

A typical list of key tasks for a cable installation project would be as follows but the sequence may vary:

1. Undertake an initial desk top study of the potential cable routes and landings in accordance with ICPC recommendation 9.

2 Consider if a desk top UXO threat and risk assessment study is required.

3 Consider the potential environmental requirements that may be generated from an Environmental Statement or EIA.

4 Refine the results where possible and scope out an initial survey if required to support the consenting process.

5 Undertake an initial survey (if required) over the primary route(s). This should extend to include any potential requirements that may have been generated from any desk top UXO threat and risk assessment study.

6 Provide initial approximate cable lengths and specifications for the manufacture of the cable.

7 Commence the installation tender process if not part of a turnkey solution.

8 Commence route engineering and refine the routes as appropriate.

9 Undertake a detailed route survey and gather as much geophysical and geotechnical data as is required to undertake the project.

10 Confirm outline installation requirements and appoint an installation contractor.

11 Undertake final route engineering and confirm cable length(s).

12 Undertake route clearance operations as necessary.

13 Mobilise transport for cable from the manufacturer to site.

14 Mobilise the cable vessel and any support vessels.

15 Undertake pre-lay grappling operations as necessary.

16 Commence the cable lay and shore ends / "J" tube pulls as per schedule.

17 Commence the main lay.

18 Complete any jointing and testing operations as necessary.

19 Transfer spare cable(s) and accessories to storage facility.

20 Compose the final as-laid RPL, SLD and reports.

21 De-mobilise from site.

2 ROUTE ENGINEERING AND ROUTE POSITION LISTS

Good route engineering starts very early on in the project. The desk top study needs to be adequately undertaken so as to enable a reasonable degree of expectation across the various cable route(s) including landing point(s). This will enable the generation of good scopes of work for the subsequent survey operations leading on to robust route engineering solutions. The relatively modest human and financial resources that are spent at this stage should robustly underpin the final route selection and installation methodologies that will need to be employed so as to achieve an overall optimum and ultimately reliable subsea cable installation.

- The Desk Top Study:

Possibly the most important part of a cost optimised and successful cable installation starts with the desk top study. This is where many early decisions taken will have an ongoing influence over the outcome of the eventual installation. It is at this time that sometimes irreversible decisions are taken on landing point selection, cable protection methods and consented cable corridors.

There is a significant risk that this initial study is carried out during the consent application process without sufficient technical installation engineering having proven that the proposed cable installation is viable.

It is for these reasons that it is essential that the desk top study is performed early on in the field design process by a company that is fully familiar with the trade offs necessary for cable installation. A range of viable options from which to select are necessary to avoid a single option for cable landing and / or routing.

Amongst other things, consider whether the desk top study should be scoped to carry out a generalised UXO threat assessment regarding the presence (or otherwise) of UXO. Depending upon the results of this threat assessment it may be necessary to extend the scope of the desk top study to carry out a full risk assessment on all or part of the route. The timing of the risk assessment should be carefully considered and should be carried out as an extension to the desk top study as the results of the risk assessment may need to be applied to the geophysical survey information in order to permit the geotechnical scope.

This Risk Assessment is often an iterative process. It may be carried out as an integral part of the Desk Study as there is synergy in carrying out the evaluation and inter relationship of all threats at the same time. The aim would be to reduce / optimize risk to the “As Low As Reasonably Practicable” level noting that there is no such thing as “Zero Risk” or 100% certainty.

Outputs from the Desk Study will consist of the Pre-Survey Route Position List (RPL) and Straight Line Diagram (SLD) for the proposed cable route. The RPL will be the centre line of the cable corridor of variable width. The width of corridor will have been selected on the level of anthropogenic threat / risk and on natural threats / risk associated with seabed and prevailing weather / tidal conditions and constraints across the project area and installation methods.

Best practice would also acknowledge that there might be a likelihood or need for active route engineering / adjustment during route survey or micro routing during installation.

The risk assessment undertaken within the desk top study will also influence the protection requirements for the cable(s) along the route(s).

Desk Top Study Technical Criteria:

- The route should avoid seabed hazards and obstructions such as wrecks and dumping grounds.

- The route should avoid areas were installation would be difficult or hazardous such as steep slopes or irregular rocks.
- The route should avoid areas of marine activity such as shipping lanes, anchorages and fishing grounds.
- The route should avoid areas of geological instability such as earthquake zones and landslips.
- The route should avoid areas where recovery of the cable for maintenance would be difficult.
- If rock placement is being considered as a solution, the potential for secondary effects should be carefully analysed e.g: scour, suspensions etc.
- The route should be reviewed for UXO or other potentially dangerous areas as appropriate.
- Where appropriate, reference should be made to EUROPEAN SUBSEA CABLES ASSOCIATION Guideline 6 for proximity and ICPC recommendation 3 for crossings as well as any other industry guidelines.

Economic Criteria:

- The route should be as short as possible.
- Appropriate means of cable protection should be considered according to seabed morphology and the results of a threat analysis noting that this might change along the cable route.
- Cable burial is typically the preferred method of cable protection. Burial distances should therefore be maximised but note that burial depth should be optimised and not excessive as this can lead to other issues.

Environmental Criteria:

- The route should be the shortest that is reasonably, technically and economically feasible.
- The route should aim to avoid known areas of environmental sensitivities, such as marine conservation areas, fishing grounds, and coastal nesting grounds if reasonably and economically feasible.
- Note however that environmental bodies are now accepting that subsea cable installation, when undertaken properly, should only have a minimal and transient impact upon the seabed and sea life.

- The route should avoid areas where prevailing climatic or sea conditions will render installation and maintenance difficult or hazardous.
- Consideration should be given to routing the cable in areas where economical use of cable protection devices can be optimised.

Permitting Criteria:

- The route must be acceptable to the owners of the offshore seabed.
- The route must be acceptable to the owners of the foreshore.
- The route must be acceptable to military authorities.
- Crossing proposals must be acceptable to the operators of existing cables and pipelines.

- The Initial Survey:

An initial survey for cable routing may be the first major investment. If required, it should be done properly and may likely also be required to inform the consent application. The survey scope should be commensurate with project requirements at this early stage prior to the viability of the project being proven.

It is essential that the correct level of geophysical and geotechnical information is gathered even at this early stage so as to provide adequate data to inform the next level of survey and cable route engineering. This will also provide the informed basis upon which cable installation techniques and protection devices are likely to be needed across the project route(s).

- Main survey:

Once the overall project concept has been accepted / consented, if the initial survey data is insufficient, the detailed survey operation can be undertaken. The results from the DTS, initial survey and UXO threat and risk assessment study will be fed forwards into the scope of work for the main pre-construction survey.

It is not considered appropriate for this guideline to detail the various techniques and scenarios that will need to be included into the pre-construction survey. The results from this survey should however enable thorough and reliable route engineering to be undertaken so as to determine not only the optimum route but also the optimum cable length(s) and protection requirements. This may also be invaluable for any future maintenance / repair scenarios.

This survey should also physically and accurately identify the location of any third party crossings that might be on the cable route so as to provide positional referencing for any crossing preparations that might be needed and also the subsequent cable installation.

Out of this survey / route engineering phase, an accurate pre-lay Route Position List (RPL) and Straight Line Diagram (SLD) will be generated. These should be compiled in accordance to the electronic format contained within ICPC recommendation 11. These RPL's and SLD's will then be used to inform cable manufacture and installation and also form the basis for subsequent export into the installation vessel navigation and cable lay computers. The RPL and SLD will also be the basis upon which tenders can be compiled for the subsea cable installation and protection package(s).

- Post installation survey:

If the installation parameters have been appropriately monitored and recorded then a post installation survey would not normally be required. In some project instances, there may however be a requirement for a selective post installation survey. The data gathered during installation should provide an alternative to a discrete full post-installation survey. The additional financial burden of a separate post installation survey might therefore be mitigated, at least in part.

If a post installation survey is required, the focus would be on:

- Confirming the as-laid position of the cable and as-laid RPL.
- Confirming the location of any joints or other bodies that may be visible.
- Confirming protection i,e: depth of burial where possible, mattress placement, rock placement etc.
- Confirming the location and lie of the cable as it crosses third party cables or pipelines etc.
- Confirming the results of any post-lay protection / burial operations.

3 QUALITY CONTROL

Quality control of the whole project from start to completion is essential. This will take numerous forms but basically it aims to ensure that the cable is manufactured, installed and tested so as to comply with all the requirements to enable it to perform for its full service life.

The skilled purchasers quality monitoring representatives are very important persons. They should be adequately briefed and their daily reports should be suitably detailed.

- Cable manufacture:

The cable will be designed and tested to known and agreed standards. It is beyond the scope of this guideline to detail the various standards that are used however, reference can be made to EUROPEAN SUBSEA CABLES ASSOCIATION Guideline 17 for a better overall appreciation.

During the cable manufacture phase, the cable will invariably have a number of factory joints. These joints might be barely noticeable from the outside of the cable. They would be expected to be nominally as flexible as the cable and have the same technical properties as the cable. Non-the-less, the location of ALL joints and any other events, should be recorded on a cable log document and ultimately the as-manufactured SLD. In the event of later issues, this document will be invaluable. The use of a skilled quality monitoring representative at the place of cable manufacture, is highly recommended.

- Cable load / trans-shipment:

During each movement of the cable, a skilled quality monitoring representative should be present. Testing to prove that the cable is still compliant after and movement should be agreed with the manufacturer. Note that the frequent application of high Voltage to the cable is not recommended. Any issues that are evident, should be diligently recorded in the cable log for incorporation into the SLD, RPL and final report.

- Cable installation:

During the cable installation phase, a skilled quality monitoring representative should be present. A testing regime to prove that the cable is still compliant during and after the installation should be agreed with the manufacturer. Any issues that are evident, should be diligently recorded in the daily report for incorporation into the SLD, RPL and final report.

Typical issues that should be highlighted and logged in the daily report at all times that the cable is being moved / installed include:

- Any damage, even to the outer roving that results in broken roving strings.
- Any installation equipment malfunction.
- Cable ship position runaway.
- Excessive tensions in the cable.
- Excessive crush forces on the cable leading to deformity.
- Exceeding the minimum bend radius of the cable at any time.
- Burial equipment malfunction.
- Malfunction of other equipment that results in impact upon the cable.
- Failure of the cable during testing / monitoring.

Compression and Buckling:

There have been a number of theories postulated regarding theoretical buckling of subsea cables. It should be appreciated that buckling under compression is a concept more appropriate to nominally “Rigid” structures such as pipelines. Subsea cables can be better regarded as being nominally “Flexible” systems and as such, bending will occur but buckling is very unlikely to occur.

It should however be appreciated that the minimum bend parameters of the cable should not be compromised at any time. When the cable is being laid on the seabed, a small amount of positive residual tension should be maintained. This so as to enable the cable to follow the seabed contours or be buried. This will also assist in generating a lay catenary in the cable. It should be noted however that excessive residual tensions could inhibit the cable from laying fair on the seabed, precipitate suspensions in the cable and poor cable burial.

The effect of the sea state on the installation vessel, particularly in shallow waters where a very short lay catenary is being used, should be carefully analysed. During shallow water installations and short catenaries, the transient dynamic movement of the lay vessel will very rapidly translate to constant modifications to the catenary. Sufficient onboard tension should always therefore be maintained, commensurate with water depth, lay speed and prevailing sea conditions, so as to prevent any compromisation of the minimum bend parameters of the cable, particularly at the touchdown position.

- Jointing:

All jointers should be properly qualified on the joint that they are making. Joints should be made in accordance with the manufacturers specifications and procedures. Jointing onboard the cable ship should be undertaken under clean conditions and in a controlled environment. It should be monitored as closely as possible by the skilled quality monitoring representative and any issues recorded.

- Post-lay works:

All post lay works that come in close proximity to or are on / around the cable, should again be closely monitored by the skilled quality monitoring representatives. They should note any significant events as above in their daily reports.

4 INSTALLATION PREPARATION AND METHODOLOGIES

It should be appreciated that there are a number of fundamental installation metholodogies that are available to be used. There is no one size fits all solution and it will need highly skilled persons on the cable owners team to assess potential solutions and decide on the optimum. A solution that is less than optimum could result in a compromised installation and even a damaged cable. A solution that is more than optimum will result in project expenditure that is higher than need be.

It is often the case that certain preparation operations will need to be undertaken prior to the installation. These might include the seabed preparation at crossing locations, route clearance of known seabed features such as out-of-use cables, well ahead of the installation (in accordance with ICPC guideline 1) would be advantageous. Pre-lay grappling operations immediately ahead of the installation operation should be undertaken so as to clear any debris from the cable route. Note that this may be an equipment insurance requirement. The vessel and equipment specification for these operations is clearly dependant upon what they are tasked to do. Typically however they would be vessels of opportunity kitted out with grappling rope and equipment. They should have good station keeping and positioning capabilities and sufficient storage space to accept the recovered seabed debris. In the case of crossing preparation, this might include the ability to place mattresses or rock berms.

Any vessel that is being used on the project should of course be within class and be properly and demonstrably well maintained. Cable installation vessels should be capable of placing the cable on the seabed within agreed tolerances.

The location for cable vessel mobilisation may also have a bearing on overall project costs and should be considered as part of the complete package.

It should be appreciated that the use of smaller cable vessels might seem at first sight to be financially attractive. This could however prove to be erroneous as the potential for increased delays due to a smaller working weather window and frequent returns to port to load additional cable, needs to be taken into account in the overall package.

Modern specific cable vessel designs of a reasonably modest specification, could be in the order of 100m / 150m +/- LOA with accommodation for in excess of 75 persons. This length has been found to optimise the cable working stability and operational capability of the vessels during inclement weather and sea conditions. The use of covered cable tanks / carousels and cable ways, is also considered to be useful in extending cable installation operation windows and the provision of a better on deck working environment for the cable, crew and associated equipment.

Whilst there is no specific requirement for Dynamically Positioned (DP) vessels, dynamically positioned (DP) vessels are becoming more and more prevalent for cable installation. Whilst simple DP can be used, it is more common to see DP2 vessels being used. It should however be appreciated that the use of the potentially more costly DP2 vessel, is unlikely to result in any commercial advantage or better lay accuracy over a typical cable installation undertaken by a simple DP vessel. The only advantage that DP2 has over simple DP is that of a certain degree of onboard equipment backup / redundancy. When working close to the potentially dangerous platforms typically found in the oil and gas sector, DP2 can have major safety advantages. Working close to the relatively benign structures found in a typical renewable energy project, or no structures at all as found on a typical interconnector project, can result in little or no significant safety benefit for the additional cost of the vessel specified.

Cable protection can come in various guises:

- Cable burial (simultaneous or post) lay
- Pre-trenching / dredging
- Cable armour (during manufacture)
- Additional split pipe application during or post lay
- Rock placement post lay
- Cable routing (route engineering)
- Warnings and notices to mariners
- Exclusion zones
- Guard vessels
- Other techniques not listed here that are being developed

All of these protection methodologies can have their place in the cable owners armoury. The use of any specific one, or a combination, will be precipitated by the findings of the route engineering solution generated for a particular project. It should however be appreciated that some of the above solutions may result in detrimental effects if a potential repair scenario might be required at any time. Some of these solutions might also be prohibited by the consents / licencing authorities.

- Shallow water

It is often the case that water depths of less than 10m are encountered during a cable installation. These can either be at the landing site or across shallow water areas. In such instances, the need for special shallow draft cable vessels should be considered. The need for shallow draft vessels / barges can again precipitate additional unexpected costs that the cable owner should be aware of and carefully evaluate. The following are some areas for consideration:

- Reduced weather window due to the underwater profile of the cable vessel / barge.
- Additional support craft needed to install / move anchors for a barge or other similar shallow draft vessel.
- Additional risk of potential damage to other plant / equipment on the seabed in proximity to the anchoring operations.
- Additional risk of vessel movement and the potentially detrimental effect on cable handling equipment and the cable itself.
- The potential need to use divers and associated specific support equipment / vessels and the knock-on effect to installation procedures.
- The reduced overall speed of installation.
- The reduced overall capability when using a mooring pattern reliant vessel to efficiently tow large ploughs if a plough burial protection solution is required.

- Deep water

Deep water in this guideline is considered as water depth in excess of 12m. This being the common depth at which most cable vessels will comfortably approach. It should however be appreciated that there are some cable vessels that may have the ability to work in water depths of around 8m. Similarly, there are some cable vessels that will not work in water depths of less than 15m. Careful consideration of these constraints should be undertaken when determining the optimum installation solution that is being tabled.

- Installation general:

The installation of subsea cables has been carried out for over 160 years and can reasonably be considered as being a very slick operation when carried out by skilled and experienced installers. A skilled installer can make the actual installation operation appear to be simple whereas in reality, it has taken them many years if not decades, to reach this level of competence. The installation may be undertaken in a number of ways. These can include:

- Surface lay:

  This is the simple, very speedy and cost effective way to install cables where the threat analysis allows.
- Simultaneous lay and burial:

  This is a typically reasonably fast and cost effective way of installing and burying the cable in the same operation. This being typically undertaken by a towed plough that has the power cable running through it although alternative equipment has been developed. The plough, whilst being relatively simple equipment, is able to provide a burial solution in quite stiff seabed conditions. Ploughs have been successfully used for many decades in the simultaneous lay and burial of subsea cables and are often considered as the primary burial device where conditions allow. Note however that to tow a plough that is installing a power cable at typical depths in a modestly stiff seabed at a reasonable speed, the cable vessel should be able to apply a suitable dynamic bollard pull.
- Surface lay and post lay burial:

  Some seabed conditions may preclude the use of a simultaneous lay and plough burial solution. There may also be instances where a section of cable has been unable to be buried by the plough for various reasons. In these instances, a specialist trenching / jetting Remotely Operated Vehicle (ROV) might be used to bury the cable after it has been surface laid. It should however be appreciated that ROV trenching / jetting machines, can typically be used in softer sediments and can cause temporary localised plumes of seabed material. They can also be slower to bury cables and often require multiple passes to achieve the required depth of burial although new equipment designs are improving depth of burial and speed.
- Crossings:

  The crossing of third party subsea assets should be agreed with the asset owner, at the planning stage, well in advance of the installation. There will most likely be a requirement to undertake certain preparation works before the cable is installed across the assets. There will also most likely be a sequence of notifications to be undertaken.
- Other protection measures:

  In certain circumstances, it might not be desireable to protect the cable by burial yet additional protection has been deemed necessary. In these instances, alternatives such as pinning and / or the application of split pipe (cast iron or polyurethane) might be needed. This can often be a requirement at third party crossings, as the cable crosses a particularly hostile seabed, at shore end landings or the entrance to "J" tubes etc.
- Rock placement:

  The use of rock placement to create berms at third party crossings, can also be a technical requirement depending upon crossing agreement specifications. Rock placement can also be used to cover the power cable and secure it to the seabed. It should however be appreciated that the placement of rock on top of the cable will most likely sterilise the cable and render it un-recoverable in the case of a fault and repair scenario. It should however be noted that there may also be secondary scouring and other environmental impact effects to consider.

- Pre-cut trenching:

  In certain areas, particularly where there are mobile sandwaves, the pre-cutting of a trench into which the cable is subsequently surface laid, might be a reasonable solution. Clearly, any trench that has been pre-cut, will need to be on the cable line and also remain open until the cable has been laid. This implies that it should only be undertaken a short time ahead of the main lay operation.

- Rock cutting:

  In some areas, there may be a requirement to protect the cable as it traverses a seabed / shoreline comprising bedrock. In these cases, the use of specialist ROV's or other techniques may be required to cut a trench through the rock.

  It should be appreciated that the depth of the trench is only likely to be such that the top of the cable is below the level of the mean rocky seabed. Trenching depths in excess of this would most likely be an excessive requirement and lead to additional cost expenditure for little if any, gain in protection.

- Diving operations;

  Diving operations are normally avoided and are replaced by ROV operations but at certain locations they are essential. These locations are typically at shore end landings and occasionally during hauls into "J" tubes etc. In all cases, diving operations should only be undertaken in full compliance with local and international guidelines and regulations such as IMCA.

5 INSTALLATION AND VESSEL EXPECTATIONS

As has been previously mentioned, subsea cable installation vessels come in many shapes and forms. The optimum vessel selection depends very much on operational water depth and expected prevailing weather conditions and sea states. For shallow waters, barges or special shallow water vessels may be used. The compromises with these types of vessels are however reduced weather windows and operating conditions due to their relatively flat underwater hull profile. For deeper waters, more conventional vessels can be used.

The use of DP for station keeping is now very commonplace and can assist in ensuring that the cable is properly laid within only a few metres of the planned route.

The selected vessel should ideally be able to continue to provide a stable platform to lay cable in agreed sea states. Technically, it should also be able to launch and recover ploughs and ROV's in these sea states and undertake surface lay of cable in worse sea states.

Cable vessels should provide good, sheltered working conditions on deck for the crew in all weathers. The ability to provide covered cable tanks / carousels and cable pathways is considered to be very desirable in extending the working window and enhance safety on deck.

When undertaking a simultaneous lay and plough burial operation, sufficient fully controlled dynamic bollard pull should be considered as being essential.

One of the often overlooked features of a cable vessel is the need to accommodate relatively high numbers of crew. There is also a typical requirement for a number of discreet office spaces with internet communication and general communication facilities for the quality assurance personnel and other supernumeraries.

The generation of comprehensive onboard procedures for use during all anticipated stages of a cable installation or repair, should be undertaken well ahead of the project. This also includes shore end landings and hauls onto platforms. Particular emphasis should be attached to hauling onto platforms so as to ensure that there is adequate room at the head of any "J" tube for the cable end rigging and turning. Proper consideration should be given to the pre-installation of cable tails from the switchgear bushings, to the cable deck where they can be easily jointed to the subsea cable without struggling to handle the heavy subsea cable around the foundation and into the bushings.

6 INSTALLATION EQUIPMENT EXPECTATIONS

All equipment onboard should be able to handle the cable within its conforming parameters at all stages of the installation.

- Cable working deck:
  The cable working deck should be sufficiently large and clear of obstructions so as to promote safe handling of the cable and various accessories as are needed during the installation. All rigging, tugger winches etc, should be within certification as required and of sufficient capacity to undertake the operations that they are needed for.
- Lifting and cranage:
  It is sometimes a requirement to lift cable ends and various accessories and devices around the vessel deck. Long lattice boom land based cranes have been used on various cable vessels. This should be avoided. The opportunity for side loading the jib and also the huge pendulum effect of a close lift, can generate safety issues and contribute to a reduced weather window. The use of "A" frames is a good option closely followed by a substantial extendable knuckle boom crane. Heave compensation can also be a desirable feature but only during specific lifts.
- Cable trackway:
  The cable trackway should be designed to be comfortably in excess of the minimum bend requirements of the cable. Spacing between rollers should also be kept to a minimum so as to reduce the occurrence of sag in the cable. The trackway should be able to comfortably support the mass of the cable and also any sideways forces that could be placed upon it at diverters etc.
- Cable engines:
  Cable engines should be of adequate design and rating suitable for all potential requirements during the installation. It should be noted that an allowance for a catenary length of at least 1.5 x water depth should be used for the installation.
  - For conducting an in line jointing scenario, the additional mass and physical dimensions of the joint should also be able to be handled.
  - When undertaking crossings, the type of additional hardware that might need to be applied to the cable, should also be taken into consideration.

  - The detail of different types of cable engines are not considered necessary to exploit in this guideline. This notwithstanding their required ability to apply sufficient tension to the cable whilst maintaining the pinch pressure within the technical limits of the cable without slipping.
  - Cable tension, speed and distance should be measured at each cable engine as accurately as possible. These to only however be used as secondary devices. The main dynamometry being a passive saddleback type device.
- Cable drum handling and associated equipment:
  During the installation of certain power cables, the use of pre-cut lengths of cable supplied on drums may be an option. These can be used for either coilable or non-coilable cables but by their nature for limited mass capacity, tend to be used for shorter cables. In this case, all drums should be securely attached to their respective under-roll stand or other drive mechanism. It is however considered essential that the drum drive should NOT be used for cable lay. A suitable cable engine and trackway should be used so as to provide the required degree of control of the cable lay.
- Cable baskets:
  Another option where longer lengths of coilable cable might be needed is to use cable baskets. These come in many guises and have been known to be able to handle cable masses in excess of 200T. They being lifted straight from the quayside / freighter and fixed to the deck of the cable vessel. Again, the use of a cable engine and associated gantry and trackway is essential.
- Fixed Cable tanks:
  Longer lengths of coilable cables can be stored in fixed cable tanks. These can be either temporary skeletal or continuous walled structures. In all cases, the dimensions of the tank and inner cone, should be compliant with the minimum cable handling parameters.
- Carousels:
  Even longer lengths of cable and especially non-coilable cables, will often use a cable carousel for storage on deck. Control of cable carousel speed and direction should be able to be undertaken, ideally from within the cable engine control area. This so as to promote close co-ordination of operations. Particular care should be exercised in the design of carousels for offshore use as there is a significant amount of flexure within a ships hull whilst underway. This has on occasion, precipitated failure of the main carousel support bearings and associated supports, placing the whole project in jeopardy and creating significant delays. The knock-on effects of which can be expensive.
- Cable gantry and loading arm:
  When using a cable carousel or a basket, there will typically be a requirement to use a cable gantry and associated loading arm. On the top of the cable gantry, a cable engine can often be found that can be used for loading cable. The loading arm will be able to laterally traverse the span of the carousel or basket and also be able to be controlled vertically. The loading cable engine will be controlled from within the cable engine control area but the traversing of the loading arm might be able to be undertaken from within the carousel or basket.
- Cable measuring dynamometry:
  The significant cable parameters of tension, speed and distance, should be recorded as accurately as possible. These parameters will not only be available at the cable engine

drivers console but also on the bridge where they would be integrated into the proprietary cable lay monitoring software. The use of tension monitoring by load cells attached to the bases of the cable engines is acceptable as secondary devices if undertaken properly. It should however be recognised that on certain occasions, the use of cable engines in tandem might be required thus potentially compromising their displays. Cable speed and distance measurement can also be taken from the track or wheel drives of the cable engines. These also should only be considered as secondary devices as their accuracy may well be compromised by slippage. The primary means of cable tension, speed and distance measurement is recommended to be performed by a passive saddleback type dynamometer with the cable running freely across it. All dynamometry to be suitably calibrated prior to use.

- Stern chute:
  The stern chute should provide the means to maintain the minimum bending radius of the cable during installation. If the chute is plain, there is likely to be stiction effects just before the cable starts to move. This needs to be recognised and compensated for as required. The insertion of rollers to try to reduce friction in the cable chute should be avoided, especially if they are un-reachable whilst at sea as they will inevitably clog up with bitumen and seize, damaging the outer serving of the cable. These rollers can also precipitate flat spotting and indentations on the cable whilst the cable is being held stationary due to point loading. The use of plain chutes will likely necessitate the application of floatation devices to the cable during shore end landings, outboard of the chute. A large rolling wheel is the best system for supporting the overboarding cable. The distance from the top of the chute or wheel to the sea surface should be kept as low as possible.

7 SCHEDULED AND NON-SCHEDULED ONBOARD JOINTING

Subsea cable joints can be classified into three discreet types: Flexible, semi-flexible and rigid. Flexible joints are more likely to be factory joints and can barely be distinguished from the cable itself. Semi-flexible joints can be made onboard cable ships with adequate space and jointing facilities. It is however the rigid joint that is more commonly found being made on a cable ship. The use of a cable vessel that does not have at least an in-line jointing capability for any lay other than the shortest, is not ideal. It is almost inevitable that in-line joints will need to be made onboard at some stage. This also gives flexibility to the direction of lay which is especially useful for larger cables where second end landings might be considered to be impractical.

All scheduled and non-scheduled jointing will require adequate space, cranage and clean controlled enclosures to enable construction. The joints will typically be made on deck, forward of the main cable engine so that the outboard cable end can be securely held whilst jointing. As the jointing operation is likely to take around 5 days, the only opportunity for bight refreshing would likely be the cable ship adjusting the catenary by the application of tension.

The deployment of the joint should ideally be undertaken in line, being controlled and held back by the cable engine applying tension to the cable. A second forward cable engine used in tandem with the first, would be useful for this operation as the joint passes through the aft cable engine. The use of a sled / cradle to provide support to the joint as it traverses the roller trackway and stern chute, might be desireable. The use of the deck crane to lift and deploy the joint should be avoided if possible.

The deployment of ANY type of joint in cradles at the head of cable bights, is to be avoided. The risks to the cable associated with this method of deployment are significant. Final splice and repair joints should always be made and laid on the straight leg of the cable bight as it departs the cable vessel. The head of the cable bight being supported on a quadrant as it passes overboard before being deployed onto the seabed. A post-lay burial operation or other protection means will usually follow this deployment so as to enhance the security of the cable. Note that the deployment of planned joints should always be done at a favourable seabed location where the cable bight can be reasonably well deployed and protected.

8 STRATEGIC PLANNING AND REPAIR OPERATIONS

It is of the utmost importance that planning for the long term storage of system spare cable should be undertaken at the earliest opportunity. It may well be that an under cover solution is desirable for cables on drums. Longer and larger cables may well require onshore cable tank or carousel storage. In all cases, it would be prudent to consider the minimum cable handling temperature.

The procurement and storage of joints and associated equipment will also need to be considered. Note that some jointing consumables might be time and / or temperature sensitive.

The setting up of a call-off maintenance agreement with a cable vessel operator together with the procurement of certain strategically important modular cable repair / lay equipment, should be considered. This could well result in a very cost-effective way of reducing overall repair costs and precipitate a potentially rapid response. The potential for a reduction in cable repair insurance premiums or indeed, the requirement for a separate insurance policy is also worthy of serious consideration.

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