ESCA Guideline No.15

Power and Renewable Energy Cable Repair 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	Nov 2015
2		Re-branding to ESCA	Mar 2016

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1 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.

2 EXECUTIVE SUMMARY

With the introduction of varied owners and ownership structures in the developing renewable energy and interconnector sectors, this guideline aims to provide high level guidance on power cable repair.

An owner operator dependant on revenues from the long-term operation and maintenance of a submarine power asset must consider submerged plant repair events. This may be considered as part of Business Continuity Planning or as part of maintenance in its own right.

3 INTRODUCTION

Subsea power cable repairs have become more common over recent years with the increased number of cables being installed on the seabed due to the expansion of offshore wind farms and interconnectors.

This guideline aims to provide cable owners with a high level overview of issues to consider in pre fault planning and repair operations. The guideline aims to provide consultees and other interested parties who need information on the processes involved in carrying out a subsea cable repair with an overview of the processes and associated issues

Repair scenarios can fall into several industry categories:

- Inter array wind farm
- Export cables
- Interconnectors
- Inter-Island distribution

Within these categories, a repair could be required at various distinct areas which require a different approach in methodology, technology and equipment to facilitate the repair:

- Shallow water
- Deep Water
- Shore end replacements
- End to end replacements

Cables within this range of repair scenarios can also vary in several parameters which are typically bounded by Voltage (AC / DC), Construction and Lay configuration.

With so many variables in power cable repairs for example: fault location, economic importance, business requirement and criticality, the repair contingency planning needs to be specific to each individual case.

4 REPAIR SCENARIOS

Repair scenarios are very often dictated and possibly limited by the availability of strategic vessels and equipment and the length of spare cable, and accessories available for the project. Repair strategies together with sufficient spare cable, storage facilities and accessories should have been considered from the outset when developing a power cable project covering all potential cable repair scenarios. Development and manufacturing risk should also be taken into consideration at procurement stage as lead times, especially for cable manufacture can be significant.

In all cases, cable and joint handling should be in accordance with cable manufacturers specifications.

This cable repair / replacement guideline is comprised of various scenarios which would relate to inter-island distribution, inter-connectors or renewable energy export / inter-array cables:

- Beach Landing: a repair / replacement strategy to be utilised when the fault occurs within these areas. Two scenarios should be assessed for the beach landing repair / replacement:
  - A repair length inserted offshore using two joints
  - A shore end replacement utilising one subsea joint and a land / sea transition joint;
- Offshore: a repair on a cable beyond intertidal areas or substation platforms, involving two joints plus an inserted length of spare cable, without disconnection of the cable from the substation;
- Offshore substation: a repair at the offshore substation, involving the disconnection of the cable at the substation, replacement with a spare cable length with one subsea joint and a re-feed into the substation;
- Inter-Array: a repair / replacement on an inter-array cable. Various scenarios should be assessed for an inter-array cable repair egg;
  - A single in-line cable joint with a replacement spare cable length hauled into the foundation structure.
  - A repair scenario including two joints with a length of spare cable spliced in.
  - Replacement of the entire inter-array cable and recovery of the old / damaged cable.

The repair / replacement process can be split into distinct steps which will be expanded upon throughout the document see Figure 1 Repair / Replacement Process.

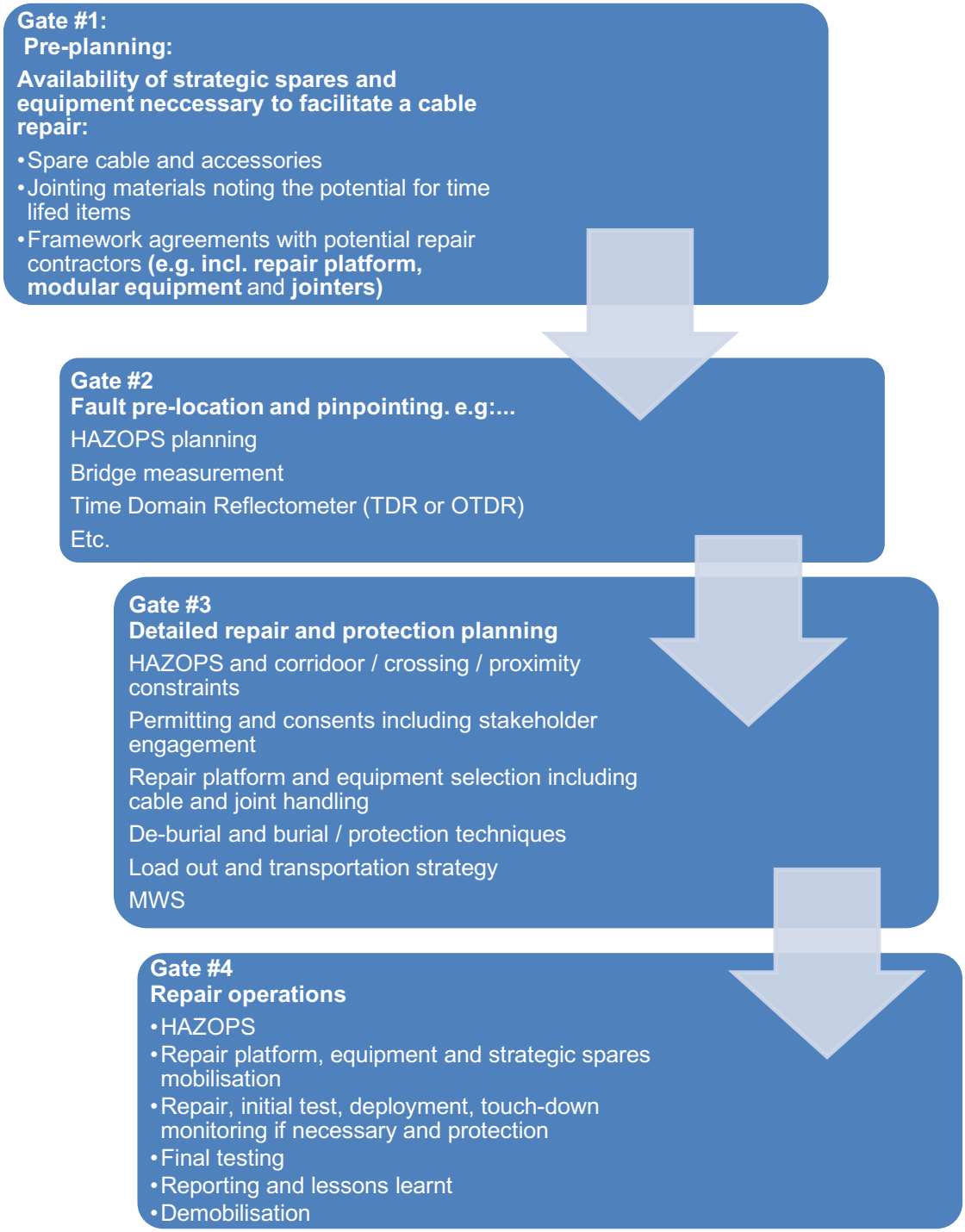

Figure 1 Repair / Replacement Process

5 PLANNING

Planning for cable repairs is essential in ensuring that a fault is able to be repaired as safely and quickly as possible. By employing an appropriate pre-planned repair strategy, repair timescales, repair costs and commercial revenue losses can be reduced.

Considering all the range of scenarios outlined in 4 above and the process gating activities identified in Figure 1, it is clear that the individual repair timescales are predicated by the individual's state of repair readiness. However, industry experience suggests typical timescales in the order of 3 to 9 months might be expected.

5.1 Health, Safety and Environment (HS&E) (Gates #1 - #4)

This is a predominant feature and must be considered throughout all stages of the repair process

Some areas that should be incorporated include:

- Legislative boundaries
- Environmental considerations
- Marine standards eg ISM code for vessel, Diving ACOPs
- HAZOP and electrical safety
- Onshore HSE and security requirements
- Offshore repair platform requirements
- Personnel training / certification requirements

5.2 Fault Location and Pinpointing (Gate #2)

Accurate fault location is a crucial factor in most repair situations, (unless the repair strategy is by cable replacement e.g. inter array cable) for the cost effective repair. (Gate #2)

There are a number of different test methods available such as Bridge Measurements, TDR and / or OTDR to name a few. Tests of power cables can be complex and time consuming and in general these tests are delegated by the Responsible Party to cable manufacturers or independent contractors specialising in this field.

A detailed consideration of fault location techniques is beyond the scope of this guideline

The Key message is that the more accurate the Fault Location, the less the repair costs will be in time, resources and materials.

5.3 Consenting, Licensing and Permitting (Gate #3)

A repair scenario can be classed as “Emergency” on “Non – Emergency”.

For definition of Non – Emergency and Emergency Repairs see EUROPEAN SUBSEA CABLES ASSOCIATION Guideline 20.

Depending on the type and location of repair work being undertaken, the responsible party may or may not require a Marine License. Consideration should also be given to any shore based licenses and permits that might be required.

Note: Depending upon where the repair is taking place, consideration should be given to the flag under which the repair platform is operating.

If the cable repair is classed as an “EMERGENCY” repair, then the responsible party may be exempt from requiring a license to undertake this repair activity.

http://www.legislation.gov.uk/uksi/2011/409/made/data.pdf

This link is to the UK Statutory Instrument with exemption for an Emergency cable repair.

Article 34 applies.

However, the devolution of responsibility has resulted in some differences of interpretation.

England:

https://www.gov.uk/marine-licensing-application-process (Note: For reference only due to Government guidance withdrawn in October 2014.)

The above link takes the reader to the MMO Marine Licensing Application page. This obviously covers English Waters.

Within that link, the following text can be found:

5.4 Notifications of exempt activities

Some activities can be carried out without a license under an exemption. Often these exemptions are subject to certain conditions that must be met before you carry out the activity. Further information on when a marine license is needed, including where an exemption may apply, can be found on the Do I need a marine license page. (Note: For reference only due to Government guidance withdrawn in October 2014.)

One common condition is that you must notify the MMO that you intend to carry out the activity before you do it. You can notify us by completing this exemption form (PDF 113KB, 1page) and emailing it to exemptions@marinemanagement.org.uk

You should include details of how you will comply with any conditions associated with the exempt activity.

Please note that the requirement is to "NOTIFY" the MMO of your intent to undertake an Emergency Repair before you do it. The other link even provides a form for you to use. Please do not get disturbed by the fact that the form does not list cables in the Exempted activity box – that is their oversight. The list reflects the greatest volume of users. Put "SUBSEA CABLE" in big letters in the first line of the Activity details field. The EUROPEAN SUBSEA CABLES ASSOCIATION are working to fix this.

Also, there is only the need to NOTIFY the MMO – not wait for reply, response acknowledgement or approval. If they have a problem with the repair operation, they will contact you.

HOWEVER, the MMO regard rock placement or other forms of protection placement and removal as falling under the old FEPA regulation outline and so still insist on a license for that work as they do not deem that to be part of an EMERGENCY REPAIR.

This is perhaps at odds with the MCAA 2009.

The devolved legislation see it differently. They exempt the repair and the supporting works.

http://www.scotland.gov.uk/Topics/marine/Licensing/marine

This is the Marine Scotland Licensing page.

http://www.scotland.gov.uk/Topics/marine/Licensing/marine/Applications

This is the applications page.

http://www.scotland.gov.uk/Resource/0039/00392525.pdf

This is the Scottish Guide to Marine Licensing document, see Article 81 in Appendix 1 Chapter 2, on Page 46 where it references the MCAA 2009.

http://www.legislation.gov.uk/ssi/2011/204/article/32/made

In Scotland, Article 32 exempts emergency cable repair from requiring a license including for what would have previously been considered as requiring a FEPA license.

http://www.assemblywales.org/Laid%20Documents/SUB-LD8439%20-%20The%20Marine%20Licensing%20(Exempted%20Activities)%20(Wales)%20Order%202011-01032011-211438/sub-ld8439-e-English.pdf

In Wales, this link shows how the parallel legislation exempts the need for a license for emergency repair including what would previously have been considered FEPA licenses that allow excavation for emergency repairs. Article 31

http://www.doeni.gov.uk/niea/marine_licensing__exempted_activities__order.pdf

In Northern Ireland, this is the same coverage. Article 32.

NON-EMERGENCY CABLE REPAIR

For pre-emptive, planned maintenance, remedial improvement or similar non-emergency "repair" work, you will almost certainly require a marine license to carry out the activity which is a longer-term planned execution type or work than immediate response intervention.

https://www.gov.uk/apply-to-construct-on-remove-from-and-dispose-to-the-seabed

(Note: For reference only due to Government guidance withdrawn in October 2014.)

This is treated just the same as an initial cable installation.

It is understood that this same approach is in place across all National and Devolved administrations.

What is not clearly defined anywhere is a consistent view of Emergency.

Most authorities will typically look at the time between the repair being required and the intention to sail and fix the problem.

For telecoms, this will be short.

For power, this may take longer to arrange but may still be classified as Emergency.

The authorities will be looking for the need to respond quickly to an incident or problem that has occurred.

For power cables, you may need to draw on the additional details of issues caused by the cable problem, such as loss of supply to a region or location, and so on. There is no guarantee this will cause your activity to be considered an emergency, but the licensing team will at least listen to what you have to say.

Renewable Energy cables may have a challenge making an emergency case for Inter array cabling but probably less of a problem for export cables.

Lastly, the rules change depending whether it is Telecoms, Power Interconnector or Renewable Energy cables that are involved. If the cable is concerned with Renewables, the rules go all the way to the edge of the EEZ and are subject to a tighter regime generally.

Applying for pre-emptive license means you will have to go through the full process as it is not emergency, but it does mean that when you do want to do the activities, you already have the approval in place so it removes such problems from the critical path.

Consider (for your renewable project) negotiating such a pre-emotive approval license for the life of the renewable Energy installation. It will have a cost, but that can be budgeted and calculated and you will not be subject to time constraints in the same way as you otherwise might be.

5.5 Cable Repair Facility (Gate #3)

When a particular fault and associated repair scenario is defined, a minimum repair facility will be able to be identified. A cable repair facility may have different requirements to that of a cable installation facility.

NB: Operational specific requirements are determined by the particular cable handling parameters and the repair environmental envelope.

For further background examples of cable installation platforms and cable repair platforms, refer to appendix 1

5.6 Repair Planning (Gates #3 - #4)

From the outset a high level generic repair MoP should be adopted and used as an operational template / checklist. This can act either as an aide memoir as the repair process proceeds or as a menu of the outline repair requirements. Owner / Operators are advised to maintain the repair plan as the particular plan is developed to ensure that the Marine Contractors MoP aligns with the Owners requirements. Any material differences need to be addressed during contract agreement or pre – operational meetings depending on the particular repair.

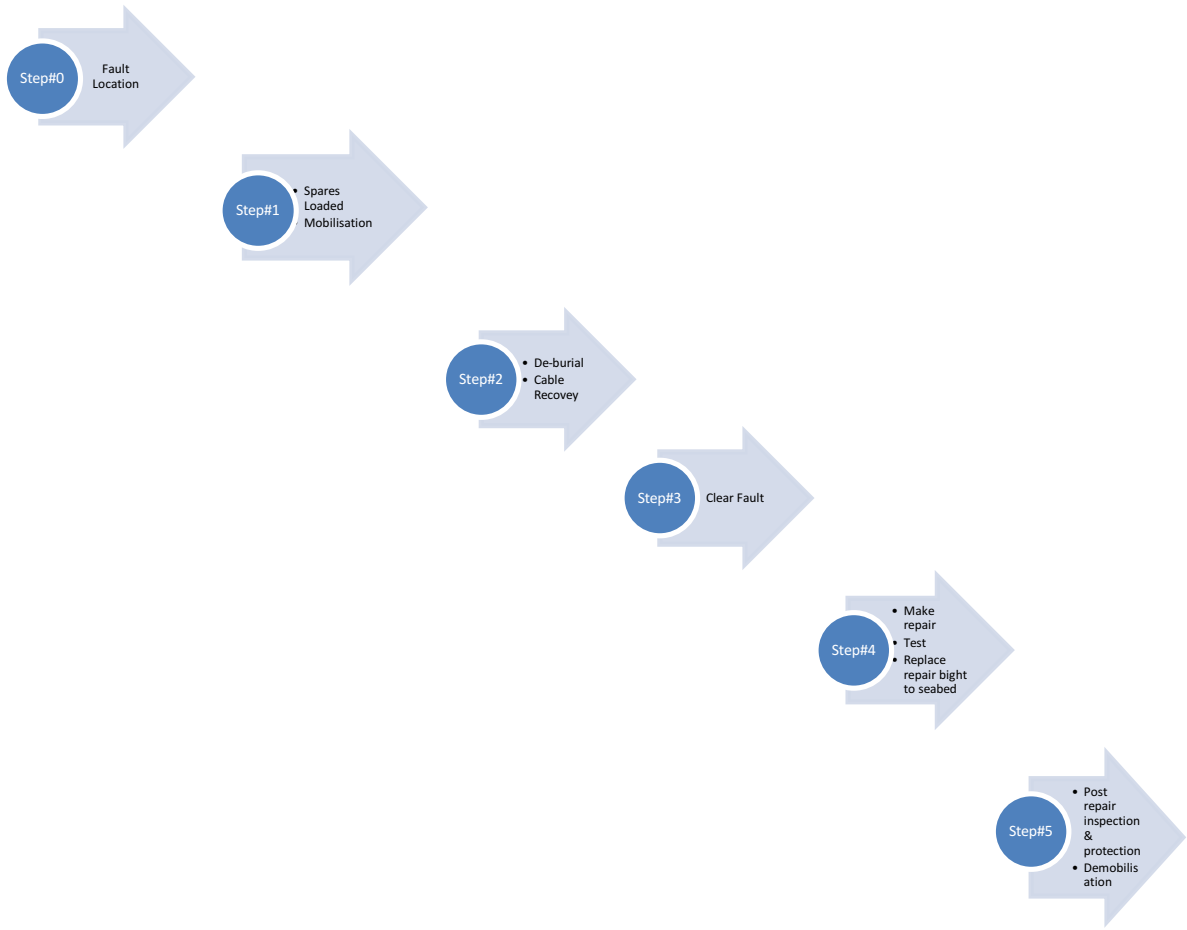

Figure 2 Generic Repair Plan Example

Comparisons between a generic repair format and particular details will identify the specific requirements for the repair. Such as the scope of the repair spread, support vessels, de-burial, post repair protection etc.

Step 0: Fault Location

- Time spent isolating the location of the fault reduces repair duration and cost
- Make sure that the fault is “Offshore!”

Step 1: Load spares & Mobilise

- The responsible party identifies and issues instructions for the maintenance facility to load
- The repair facility is mobilised and transits to site

Step 2: Cable location, de-burial, cable ends recovery

- Establish the location of the cable on the sea bed
- De bury cables and recover the cable ends

Step 3: Clear Fault

- Remove fault
- Confirm the cable tests clear both ways

Step 4: Make repair

- Insert repair section and make repair joints
- Return repair bight to seabed

Step 5: Repair Completion

- Repair Confirmation Tests
- Restore and inspect cable protection measures
- Demobilisation
- Post Operation Documentation
- Post Operation Review

5.7 De-burial, Post Repair Burial, Remedial Protection and Inspection

In water depths down to about 1500 metres it is good engineering practice to provide a cable with the best available protection from external aggression by burial during installation. This being the case, it is almost certain that de-burial and subsequent re–burial will form part of most repair operations. Where burial is not achieved to the degree desired, other remedial protection operations may be undertaken. From an operational economic stand point the minimum amount of cable should be de-buried to affect a repair. It can be appreciated that fault localisation has a direct bearing on this.

This subsection identifies common solutions used to de-bury, bury and provide additional protection

5.7.1 Jetting

Jetting relies on a high pressure water flow from nozzles, which fluidises the seabed. As the jetting tool is moved along and around the cable, the seabed is fluidised moving sediments and exposing the cable making it possible to hook and recover the cable.

Jetting may be performed in a number of different ways most common of these for maintenance are ROVs or Divers

5.7.2 Mass flow excavation

Another means of de-burial is the use of a mass flow excavation device, which generally consists of a high-flow turbine in a cylinder which can be deployed from a crane on board a small vessel. It "blows" large quantities of water towards or "sucks" seabed material away from the area which needs deburial. However tends to only work in sandy / non-cohesive seabed.

5.7.3 Post-Repair Burial

Specially adapted loughs and water jetting equipment can be used for simultaneous cable laying and burial, or for post lay burial.

A post lay burial operation may be performed at a convenient time after the cable has been laid, usually from a smaller vessel. The cable is, however, at risk during the time window between laying and burial.

5.7.4 Post Repair Additional Protection

In the event of remedial cable protection being required on the cables, the following solutions could be applied:

- Split pipe protection
- Plastic protectors
- Mattressing
- Rock placement

5.7.4.1 Split Pipe Protection

Articulated split pipe protection consists of interlocking cast iron (impact resistant) pipe halves, which lock together to protect the cable from abrasion or other external damage. Split pipe protection can be self-locking and fixed to the terminations, therefore no bolts may be required. Articulated split pipe protection is manufactured in approximately 0.5m lengths, and can be installed onto the cable onboard ship during the lay out or by divers following cable installation.

5.7.4.2 Plastic Protectors

Plastic protectors are a form of split pipe cable protection, which comprise of cylindrical half shells moulded from high performance polyurethane. Each half shell overlaps and interlocks to form close fitting protection around the cable. Each shell is secured in place using corrosion resistant banding, negating the need for bolts. Plastic protectors are manufactured in lengths of approximately 2.0m with various internal diameters and flexing characteristics to suit the required minimum bending radius. Plastic protectors can be fitted on deck as the cable is being installed, or fitted post lay by divers.

5.7.4.3 Mattresses

Mattresses are often concrete and are designed to work as a highly resistant stabilisation and protection system for pipelines, cables and umbilicals. Mattress designs often consist of high strength concrete segments linked together with a network of polypropylene ropes to form a continuous but flexible barrier. Most mattresses can be installed with a quick release installation frame and come in various sizes appropriate to the application.

5.7.4.4 Rock-Placement

Specialised rock (such as granite of a certain cross-sections) is placed on the area using a fall-pipe or off the side from specialist vessels. This serves to act as a stabilisation and protection system, but, caution should be exercised regarding the potential side effects of rock placement in causing scouring and sterilising the cable.

6 REPORTING

One of the most important aspects, often overlooked, during repair work is post operational documentation. Such documentation is important for a number of reasons:-

Maintenance records are required for the operational life of the system, in support of ongoing operational decisions as well as to complete post repair notifications e.g. UKHO, KISORCA etc.

It is normal to keep a detailed account of the evolution of the system parameters over its life such as losses, measurement, splice lists, route position lists, depth of burial, spares and equipment inventories etc.

It is recommended that Owners / The Responsible Party define their documentation requirements and drawing standards as part of their maintenance policy and invest reasonable time in assuring the appointed maintenance contractors adhere to policy.

7 APPENDIX 1

7.1 REPAIR FACILITY EXPECTATIONS

As has been previously mentioned, subsea cable repair facilities come in many shapes and forms. The optimum 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 however are 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 placed within only a few metres of the planned route.

The selected vessel should be able to continue to provide a stable platform to repair cable in agreed sea states. Preferably, the vessel should also be able to launch and recover any ROVs if required in these sea states and undertake surface lay of cable in worse sea states. Note however that cable

touchdown point refreshing is considered to be essential for any scenario, particularly considering the extended timescales anticipated for a power cable repair so as to minimise the potential for cable serving damage and fatigue stress.

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.

One of the often overlooked features of a cable facility 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 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.

The deployment of the repair joint should ideally be in the straight leg, not the head of the repair bight, the head of the repair bight being subsequently deployed using a quadrant. Thus minimising the risk of flipping when deployed onto the seabed and promoting subsequent cable protection measures. It is however appreciated that some repair joints might need to be deployed at the head of the bight. In this instance, extreme care should be exercised to balance the outboard cable tensions in each leg before carefully deploying the joint. Care should also be taken to ensure that no rigging is attached outboard of the repair joint and bend restrictors that might subsequently lead to compromisation of the MBR and integrity of the cable.

7.2 Repair vessel typical deck / bight layout

Generic deck layout

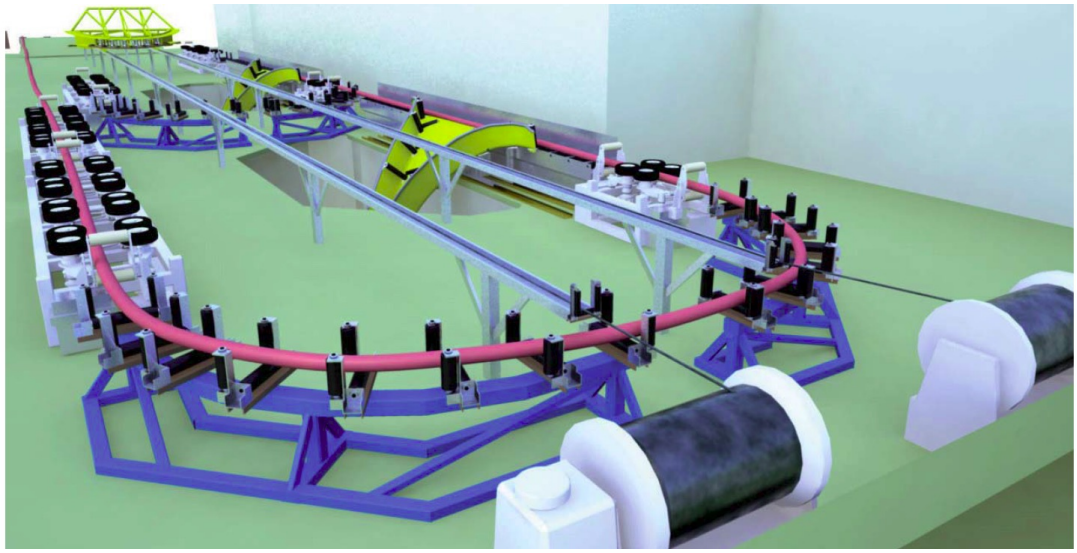

Figure 3 Illustrative Cable Repair Set Up

7.3 Cable Repair Support Vessels

Depending upon the repair strategy and the selection of CRV, a variety of support vessels may be required to perform support task such as anchor handling and dive support operations.

Multi-cats are extremely flexible multipurpose work vessels with the ability to undertake almost every task. They are ideally suited to:

- Towing and pushing operations
- Buoy and anchor handling
- Dive support
- Pollution response
- Dredging / deburial support
- Survey support

Multi-cats can also provide other support equipment such as:

- Deck cranes
- Winches
- Good working deck space

A dedicated Cable Lay Vessel (CLV) is designed for the task of cable installation but, by careful design from the outset, can also often be utilised as a Cable Repair Vessel (CRV). A dedicated CRV might have a lower deck load requirement for shorter repair lengths, ample deck space for jointing enclosures and remedial burial tools on deck as well as appropriate accommodation.

Vessels vary in their suitability depending on the combination of many criteria:

- Station keeping ability
- Load capacity
- Deck arrangements
- Water depth
- Local conditions
- Manoeuvrability
- Crane/A frame capabilities

A repair vessel would ideally have a large working deck with sufficient space to mobilise for repair including:

- Cable engines
- Winches
- Cranes and/or “A” frame launch system for relatively long length rigid repair joints typically used in power cable systems
- Cable chute(s)
- Dive equipment
- Jointing enclosure (climate controlled)
- Burial equipment
- Spare cables storage and accessories

Depending upon the cable repair location and port facilities, a significant level of accommodation may also still be required on board a CRV. Depending upon the scope (i.e. de-burial, WROV/Divers) it could be the case that the required accommodation is more than that of a CLV.

There are several main differences in the vessel that could be selected for undertaking a power cable repair:

Propulsion: propelled or not propelled. Non propelled vessels have a requirement for additional support vessels to tow and handle anchors.

Spud legs / Jack up legs: use of spud legs or jack up legs can remove the need for anchors. However, on a barge without propulsion, movements may be best controlled within a mooring spread.

Dynamic Positioning (DP): DP systems can allow a vessel to remain on station without the need for anchors. (note that shallow water may however preclude the us of DP systems)

Grounding out: in shallow water the ability of the CRV to ground out could be important when trying to remain on station against tidal swings during prolonged jointing operations.

Repair requirements for cables.

7.4 Main Equipment requirements to consider include:

- Cable spread descriptions
- Cable protection system
- End caps (cable seals)
- Hermetically controlled jointing area
- On-board cable storage – Carousel/Reel/Tank
- Lifting crane / A Frame

- Any special joint handling requirements
- Cable bight deployment and set-down quadrant
- Recovery and deployment winches
- Lifting accessories and rigging
- Linear or drum cable engine
- Cable rollers / double highway
- Diving / WROV spread
- Survey and positioning
- Support frame for recovery and launch of cable(s)
- Facilities to store damaged cable section(s) for post operation investigation (insurance)

7.5 Site Specific Considerations

- Mooring analysis and station keeping capabilities at joint location
- Dynamic and static cable analysis
- Weather conditions on site.
- Operations at shipping lanes / Marine traffic
- Tidal range / currents

Optimum power cable repair scenario's can be very broad ranging. The engagement of skilled personnel and contractors at an early stage, is highly desirable. Generic procedures would benefit from generation well in advance of any actual repair scenario so as to enable the rapid commissioning of a repair solution with the minimum of delay and potential lost revenue.


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