NEW TOOLS TO IMPROVE THE SPEED AND EFFICIENCY OF REPAIR OPERATIONS

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Abstract: The recent ROGUCCI report published in April 2010 identified competition for limited resources as one of the main reasons for extended duration outages of damaged undersea cables. A limited number of ships with the specialized crew and equipment needed for accessing and repairing subsea cables are available worldwide. This paper describes how using sophisticated 3D cable modeling technology to monitor and control, in real-time, the cable bottom tension and touchdown conditions can increase the speed and efficiency of an entire cable repair operation. This cable repair management system is the logical extension of the GIS based integrated planning and installation software packages that have been successfully used by commercial cable installers for the last decade.

1. INTRODUCTION

The network of undersea cables has been steadily increasing and aging over the years. This has resulted in an increasing number of repair operations and increasing demand for the limited supply of specialized repair ships and personal [1].

While cable planning and installation operations have been greatly streamlined and integrated with GIS platforms that include sophisticated 3D cable modeling technology for the control and monitoring of submarine cables, repair operations have yet to take advantage of this technology. Current repair techniques are still based on simple quasi-steady equations that force installers to use slow retrieval speeds and apply large tensions on the cable.

The cable repair management system (CRM) being presented has been created by expanding the existing integrated cable planning and installation software with which cable installers are already familiar.

Specifically, the CRM: (a) simplifies the data sharing process between various stages of the operation by using integrated and common GIS databases that are easily accessible by planners, installers, and owners; (b) provides real-time cable shapes in the water column to improve recovery techniques, including the capability to increase vessel speed while minimizing cable bottom tensions during recovery, thereby minimizing cable dragging and snagging on the seabed and disruption of ocean habitats; (c) overlays current cable position on positional data of existing cables and seafloor obstacles, thereby decreasing the probability of cable fouling in the repair vicinity; (d) includes tools to assist in all phases of repair operations from the planning of grappling to the redeployment of the spliced cable.

2. INTEGRATED SOFTWARE

Figure 1 illustrates the sequence of events for a cable project, starting with cable route planning and ending with installation and repair. The large ribbon represents a GIS database that contains all the information for a cable project. GIS databases are commonly used to record and recover data that need to be geo-referenced and are, therefore, ideal for submarine cable projects.

The process shown builds from the initial route concept and progressively adds information such as survey data and cable assembly requirements. The initial RPL,

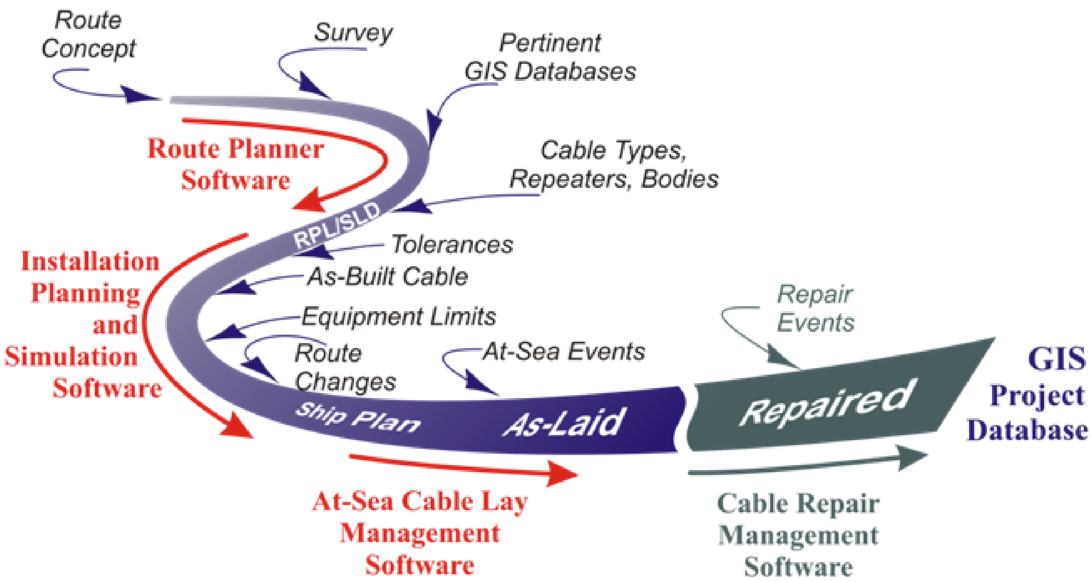

Figure 1: The submarine cable project GIS database expanding from the initial route concept to the final as-laid and the new cable repair management (CRM) system.

Ship Plan and as-built cable are milestones leading to the final as-laid cable. The database can be maintained by the owner or his representative and provided to planners, installers and repair vessels.

The illustrated process uses a single non-proprietary project database that expands as the project develops and grows. Data such as bathymetry, soil types, side-scan images, Route Position Lists (as-designed, as-laid), cable assemblies, and installation notes can be easily added. With seabed being increasingly cluttered, it is important to maintain and have easy access to all the relevant information [2].

Planning and installation software share a common database and user interface. The installation planner is therefore familiar with the software used by the installer. The common database and the user interface goes beyond the software; planners and installers have a common basis for thinking about and discussing a project [3].

This sequence has now been completed by including software designed for the maintenance and repair of submarine cables. All the information that was used in the cable planning, engineering and installation can now be available for at-sea repair in an easy-to-use format. When the repair operation is completed, the final repaired cable can be added to the same database.

3. IMPROVED CABLE RETRIEVAL

Increased tension on the seabed during recovery increases the risk of damaging the cable due to either exceeding the cable's working strength or excessively dragging the cable along the seabed. While it is theoretically possible to recover cable while maintaining essentially zero bottom tension, this is not recommended as any cross currents or lateral offset of the ship from the cable path will create a U-shape in the cable, drag it on the seabed, increasing the likelihood that the cable will be damaged by snagging on bottom outcrops during retrieval. Maintaining a small, but positive bottom tension is recommended for cable retrievals.

Shown in figure 2 are the steady state cable bottom tensions of a representative lightweight protected cable being recovered in 2000 m of water. The bottom tension is given as a function of retrieval speed and cable angle at the ship. Note that a modest increase in retrieval speed or decrease in cable angle has a significant effect on the cable bottom tension.

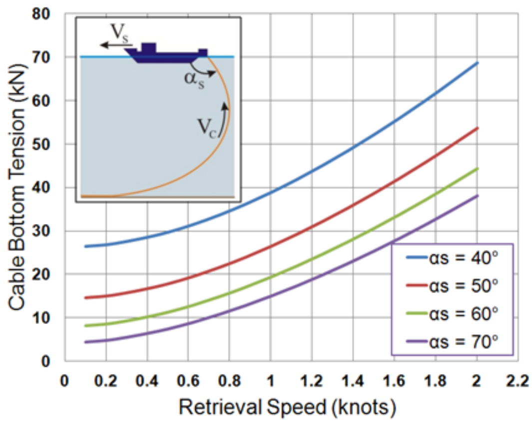

Figure 2: Steady-State cable bottom tension vs. retrieval speed for light weight protected cable (4 N/m, 43 Knot-deg) being recovered from a depth of 2000 m.

Conventional cable recovery techniques do not provide cable engineers with an accurate understanding of, or control over, the cable tension at the seabed. They use top cable angle near the ship as an approximate measure of the bottom tension. Thus, in order to avoid the possibility of retrieving sections of the cable with zero tension at the seabed, cable engineers tend to use values of top cable angles no larger than 60-70 degrees. However, for this range of top cable angles, the retrieval rates cannot be high as the bottom tension will quickly increase as retrieval rate increases, potentially damaging the cable. Thus, typical retrieval speeds would be less than 1 knot.

An accurate, real-time cable model provides the cable operator with the full cable configuration (i.e., cable shape and tensions as it is being recovered). With this information, the cable can be confidently recovered with larger top cable angles, decreasing the tension in the cable and the risk of cable damage, and allowing for faster recovery speeds.

Using the new tools, it is possible to quickly adjust the cable payout rate to maintain the desired cable tension at the touchdown point. As table 1 shows, the use of the CRM to retrieve cables results in almost two times the retrieval speed keeping the same top and bottom tensions, (2 knots vs. 1.1 knots). If the cable were retrieved using conventional techniques at a retrieval rate of 2 knots, the bottom tension would have more than doubled.

	Retrieval Rate (knots)	Top Tension (kN)	Bottom Tension (kN)
CRM (α_s = 120°)	2.0	29.2	21.2
Conventional (α_s = 60°)	1.1	29.4	21.4
Conventional (α_s = 60°)	2.0	52.4	44.4

Table 1: Comparison of top and bottom tensions for cable retrieval using CRM system and conventional techniques.

The CRM's capability to control the cable seabed tension has been validated on numerous occasions using real at-sea test data [4, 5]. The range of uncertainty in the computed touchdown cable tension oscillates between 2% (for heavy cables) and 4% (for lighter cables) of the values of top cable tension. For a typical retrieval of a light weight cable in 2000 m of water, this corresponds to maximum uncertainty of ± 800 N at the seabed. Thus, by keeping the calculated value of cable touchdown tension slightly above 800 N, the cable engineer is confident that some residual, but low, value of cable tension is maintained at the seabed during retrieval.

In order to minimize the amount of seabed dragging, the lateral component of cable tension at the touchdown location must be minimized. Figure 3 shows that the ideal configuration for cable recovery in the presence of currents involves placing the ship up current of the cable path and controlling the cable's bottom tension to vertically lift the cable from the seabed. If the cable path contains turns, the ship must also be offset from the path to maintain a vertical lift-off point at the seabed.

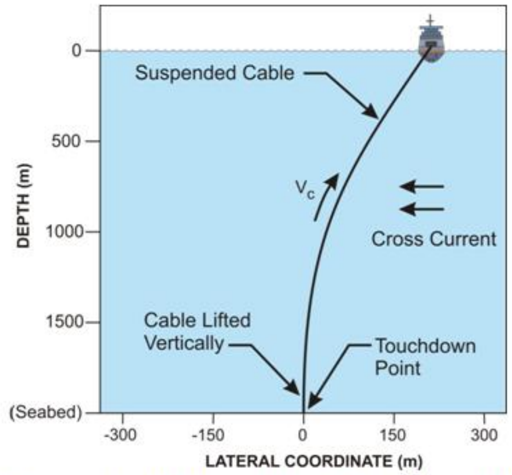

Figure 3: Ideal configuration for cable recovery in the presence of cross currents.

The cable repair management system allows the cable operator to make necessary changes to the ship instructions on the fly as situations evolve at-sea, i.e., currents change, unplanned ship stops, etc., while maintaining desired bottom tension.

4. REPAIR PROCESS

This CRM system extends and greatly enhances the existing capabilities of the planning and cable installation software to make it suitable for repair operations. It includes powerful GIS documentation, real-time interactive displays and powerful tools for cable repair. Key features include:

Access to all critical data: All the relevant data available for the repair operation can be easily accessed. Detailed bathymetry, as-laid cable location and slack, burial depth, bottom roughness, other cables and pipes, seabed soil type, etc. can be viewed for the repair area. With easy and comprehensive access to all known information, better and quicker decisions can be made for all aspects of cable repair.

Availability of key assistance tools: The CRM includes several tools to help make key decisions before and during the operation. It includes a calculator for the required grapnel rope length for any user-defined grapnel assembly and the expected bottom tension, and a buoy selection tool that accounts for the buoy rope and expected ocean currents. With these tools the user can select and/or create an assembly appropriate for any particular operation. This assembly can be printed out in schematic form for easy rigging. During grappling, the user can use the grappling watch tool to display the estimated time to grab/cut the cable based on the current grapnel catenary shape and calculated touchdown position.

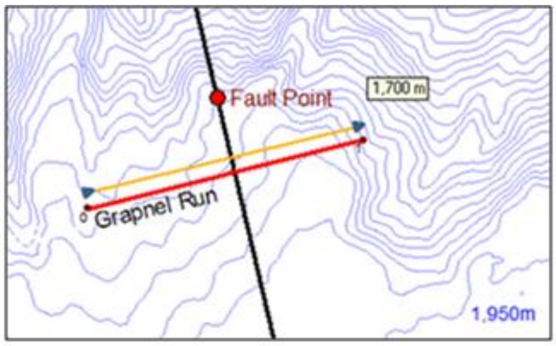

Figure 4: CRM plan view display showing a grapnel run route.

Provide Guidance in key operations: The repair management software will log and process data from a variety of sensors on the repair vessel. Input data such as ship position and heading, cable payout, cable tension and ROV location can be monitored in real time and displayed. With sensor input, the cable model computes real time cable solutions for the ongoing operation and displays and logs critical information. A key feature of the CRM cable model is its capability to model real-time cable shapes and tensions for multiple cables simultaneously (Figure 5 is a display of a cable splice being deployed).

Provide displays in clearly understood terms: With real time input, the CRM provides displays to the cable engineer that are meaningful in terms of the current operation (e.g., ROV operations, cable recovery, laying, grappling, buoy placement). For instance, when recovering a bight or dragging a grapnel, the theoretical/calculated tension is compared to the actual tension, thus providing either an early warning of problems or an assurance that the loads are as expected.

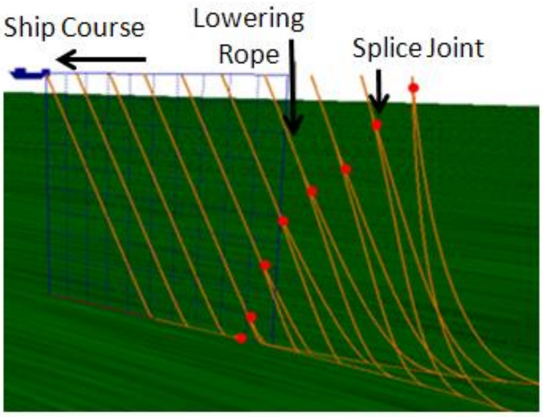

Figure 5: CRM display showing a splice joint being lowered.

The CRM also provides tools for working directly on the GIS screen, whether adding lines, notes, showing distances, displaying depths, recording events, computing cable alignments and/or shapes. These events can become a part of the permanent repair record. All components are displayed in real time on the same plan view as the ship and ROV locations, computed cable shapes, the RPL, bathymetry, and any other pertinent GIS database information. Additional information can be loaded when needed and then hidden to prevent clutter.

Reporting: The final repaired cable is added to the project's database. Easy tools exist that allow for the updating of the as-laid RPL and new cable assembly simultaneously. Additional fields in both the RPL and Cable Assembly databases allow for additional information to be stored such as fiber types, chromatic dispersion, or any characteristic of interest to the owner. All events and notes are logged into a searchable database and can be cross-referenced to any other data logged or computed at that time. A report can be generated at the end of the repair listing all events and any corresponding data such as ship and ROV coordinates.

5. CONCLUSION

Running on a standard, commercial-off-the-shelf PC and in a GIS environment, the cable repair management software accurately simulates all phases of cable repair, including: grapnel launching and cable searching, lifting the cut cable, buoying the cable, cable retrieval for fault and spliced cable re-deployment.

The new software is an extension of the validated cable installation planning and at-sea cable lay management software with which cable installers are already familiar.

These recent improvements are important to owners of cable systems and cable repair engineers as they help to increase the speed and reliability of the repair operation.

6. REFERENCES

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