Marine Tools, Vessels, and Methods for Effective Cable Protection: More Important than Ever

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Abstract:
External aggression on the near shore sections (less than 1500m water depth) of a submarine cable system remains the single highest risk impacting network reliability and availability. Cable burial remains the most cost effective and best form of cable protection against fishing and many anchor threats. Recent advances and experiences with marine tools (ROVs, plows, and vessels) and methods used to install and bury undersea cables help to achieve optimum protection against these threats. Execution is the key. Selection of the appropriate vessels, marine tools and well trained crews remain fundamental to long term cable protection.

1. Introduction

External aggression on the near shore sections (less than 1500m water depth) of a submarine cable system remains the single highest risk impacting network reliability and availability [1,2]. Cable burial remains the most cost effective and best form of cable protection against fishing and many anchor threats. The marine planning and installation program is fundamental for maximizing overall network reliability over the life of the system. Execution is the key. As end clients and purchasers of bandwidth demand more data on cable faults and depend upon the reliability of cables that carry their traffic, a focus on cable protection remains paramount. While seabed stiffness is important in predicting and achieving burial, other features such as slopes, cable and pipeline crossings, and currents also impact plow operations and burial success. Planning plow deployment and recovery is critical for maximizing burial and avoiding damage to the cable and plow. Instrumentation and control systems, operator skill, visibility, calibrations, and handling systems all play a part. The importance of a good desktop study (DTS), assessment of external risks, an accurate route survey, and burial assessment directly impact final burial results. This analysis allows the supplier and client to jointly determine the burial depth necessary to protect the cable in the seabed conditions that exist along the route; where 1.5m target burial is sufficient and where 3m target burial is justified from a lifecycle cost analysis.

2. Elements of a Successful Burial Program

A successful burial program is the result of careful and thorough attention to basic elements, including:

a. Route Planning
b. Survey
c. Burial Feasibility Study [3, 4, 5, 6, 7, 8]
    Planning plow launch and recovery
d. Tool selection
e. Burial operations
- Key vessel capabilities
- Plows and Remotely Operated Vehicles (ROV)
- Crews and Operators
- Methods and Procedures
- Safety

A previous SubOptic paper focused on route planning, survey and the burial feasibility study of the program [9]. The following paper carries this forward with a focus on the marine plows, ROVs, vessels, crew capabilities and operations essential for successful burial.

3. Plows – Industry Workhorse: Selecting the appropriate tool for the Job

Cable burial plows are the workhorses of the industry and have been since burial was first introduced as a method for the protection of undersea cables decades ago. The tools are built to operate in very rugged seabed environments of stiff soil, rock, and often boulder fields and operate up and down slopes. They require sophisticated sensors, including cameras and sonar, and control systems to measure and control burial depth, tow tension, pitch, and roll.

Burial Requirements

The burial requirements needed to mitigate the risks that are defined in the hazard and risk assessment of the DTS, are applied to the tool selection as follows:

Burial Depth

Plows range in size and capability; selection is based on the burial depth required. Burial to 1m and 1.5m is standard for most parts of the world where seabeds comprise sand, silt and clays. These stiff seabeds do not allow penetration of fishing gear beyond 0.6m to 1m. Plows with 1.5m burial depth capability will continue to see wide use in many locations and well into the future.

In other regions, predominantly in Asia on the continental shelf of China, 3m burial continues to be required to protect cables from stow net anchors that can deeply penetrate the soft soils found there. Recently installed systems and plans for new cables specify 3m burial in this region.

Deeper burial continues to be required in anchorages. The MPA in Singapore continue to require 4, 6, 10m burial within the port limit, depending on seabed conditions. Injectors and rock cutting tools are used to cut a trench for the cable in these special areas. These tools will continue to see use there.

Water Depth

Risks of external aggression due to fishing (trawling and grappling for traps) typically occur in less than 1000m water depth (WD). Some trawling as well as trap sets occur at the continental shelf break, but in less than 1200m WD. Deep water trawl fishing to 1500m WD has been seen in some parts of the world, but is not typical. There have been rare requests from some clients to bury to 2000m WD.

The Move to 3m Plows – Appropriate Use and Selection

When deeper burial is warranted, we consider two basic types of 3m sea plows used in the telecommunications subsea cable industry; one uses an articulating plow design to reach 3m depth and the other is a fixed or rigid plow share. Both of these systems work well in the conditions for which they were designed; however there are important operational aspects that are considered when making a tool selection. Note also that each plow operates and calculates burial depth differently.

A.) Articulating Plows

Articulating plows pivot along the horizontal axis (articulate or fold in half) to achieve 3m burial. The articulated plow achieves full burial by hinging the aft end of the plow downward in combination with the aft pitch. (Figure 1).

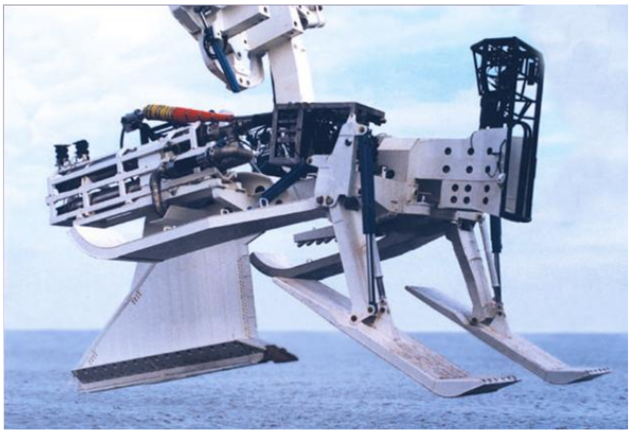

Figure 1 – Articulating 3M Plow

B.) Rigid Plows

Rigid plows of this design have a fixed frame, an angled, thicker and heavier share and a rear stabilizer that can be adjusted 5 degrees above horizontal to reach 3m burial (Figure 2).

Figure 2 – Rigid 3M Plow

Achieving Desired Burial Depth

Burial Depth less than 2.2m

Both types of plow use the same method to reach pre-determined burial depths when the burial depth is less than the length of the share. They both use a combination of forward skid and rear stabilizer movement to adjust penetration of the share. For desired depth of burial (DOB) that is less than the height of the share, both plows are operated much the same:

- In softer soil the forward skids and rear stabilizers are raised to preset heights to allow for a desired depth of burial (‘fixed’ mode).
- Where the seabed is firmer, the plow is configured by raising the forward skids and leaving the rear stabilizers in ‘float’ mode to obtain desired burial depth. In this mode of operation, both rear stabilizer transducers can be averaged to better refine depth of burial readings.

Burial Depth between 2.2 and 3m.

When DOB is required to a depth greater than the length of the share, the two plows achieve this in different ways.

The **articulating plow** uses the principle that if the geometry of the plow is changed such that the rear of the plow is angled down, the trailing edge of the share will protrude deeper than it could if the plow were to remain rigid. This requires that the rear of the plow can sink, as there is no more movement in either the forward skids or the rear stabilizers. This articulation acts to effectively extend the share length to allow a greater DOB than the length of the share alone. However, the soil must be soft. Its ability to obtain maximum burial depth is hampered in harder soil types as the heel of the share is being used for cutting and the plow relies fully on the rear of the plow being able to sink. (Figure 3).

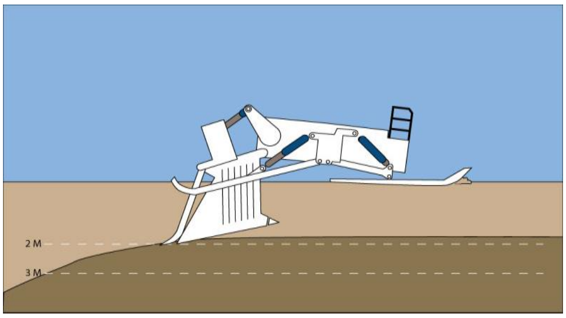

Figure 3. Articulated plow encountering a hard subsurface layer. Reduced burial results.

The **non-articulating or fixed share plow** has a longer share, but also allows a further height adjustment of the rear stabilizers above the horizontal. The combination of this extra movement, a heavier share to help with sinkage and the different share angle of this design allows for an aggressive cutting action by engaging the additional plow tips. These three features combine to obtain a greater DOB than the length of the share alone can. (Figure 4)

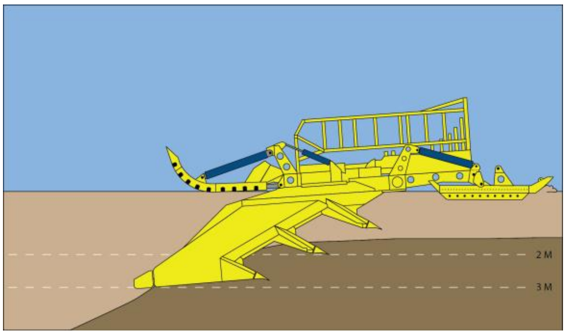

Figure 4. Rigid plow encountering a hard subsurface layer. Maintains deeper burial.

Plow Share Design

Another aspect of these specific articulated plows is that they have lighter, narrower vertical shares and therefore require less force to pull the plow at a certain speed and given burial depth.

The rigid plow requires greater pulling force and slower speeds to obtain greater burial depth due to the heavier, wider and more aggressive share design.

The specific cable ship, launch and recovery system, and tow winch are matched to the capabilities and the draw bar and handling requirements of the selected plow.

5. Burial operations

Burial consistency and success relies on the knowledge and experience of the crews that calibrate, operate and maintain these complex tools. The plow operator can control several plow parameters to achieve the desired burial. These include: stabilizer height and plow pitch (to set burial depth) and plow tow speed.

Burial depth is determined by an algorithm programmed into the control software taking input from sensors on the plow including: forward skid position, plow pitch and depressor height. In the case of the articulated plow, the hinge angle is added into the equation. These are all set by the operator. [10]

Plow pitch is controlled by plow skid position and the hinge angle in the case of an articulated plow. In a perfect seabed, the plow tends to rotate toward level or zero degrees of pitch. With a fixed share plow, the depth is simply controlled by the forward skids. As the skids are raised, they create a negative or forward pitch. This results in the plow digging in until it becomes level again. As long as the plow operator keeps forward pitch, the plow will attempt to dig in and increase the burial depth.

With an articulating plow, the settings for holding an aggressive dig angle are more complex. Hinging up of the share causes an aggressive burial angle at the plow share tip. Both raising the skids and movement of the share generally work hand in hand, but requires a crew experienced with the operation of an articulated plow.

Setting the appropriate **plow speed** is one of the more important operational parameters for achieving good burial. For speeds over approx 0.35 kts, plow speed and burial depth are directly related. In general, the lower the speed the greater the burial achieved; the specific relationship is dependant of seabed type. In sandy seabed the speed vs. burial depth relationship is more sensitive than that of clay seabed.

Below approximately 0.35 knots, there is little increase in burial depth by slowing further; slower plowing only adds to the program duration with no improvement in burial.

Launch and Recovery
Launch and recovery of a plow are best on firm, flat sea beds, so special attention is given to plow launch locations. One such situation occurs with cable and pipeline crossings that require plow recovery before and launch after the crossing. Crossing areas resulting in unburied cable will most likely require post lay burial, hence the operational parameters of the ROV trenching vehicle must also be considered.

In recent years, improved seabed surveys with far greater accuracy have enabled better planning of plow launch sites. While plows are rated up to a maximum of 30 degrees of pitch and 20 degrees of roll, landing on or recovering from seabeds approaching the maximum is avoided both for the safety of the cable and the plow. Operational limits of 15 degrees pitch and 6 degree roll are typical to avoid damage to the cable and plow.

Calibration and Plow Maintenance
Correct and comprehensive calibration of the equipment is an essential element of a successful installation. Accurate plow telemetry is required for the operator to maximize burial results.

Proper maintenance is essential to a successful burial program. Each breakdown on the seabed equates to a recovery and plow skip that will have to be addressed during the PLIB operation. Though post lay burial with an ROV will bury the cable to a safe depth, it will increase the cost of the installation.

Crew and Training
Maximizing burial results requires an experienced and competent crew to manage the complex and dynamic interaction of sea plow and changing bottom conditions.

Many hazards such as high currents and bad weather during plow operations cannot be avoided. Success in these situations is a function of proper planning and a well trained and experienced cableship crew and the inherent station keeping capability of the ship. The decision to continue operations, stand by with plow on bottom or recovery of the sea plow has a direct impact on both results and costs. Conditions such as being in the shelter of a landmass or wind and sea direction will often allow an experienced crew to operate beyond the published parameters of the equipment in use. This experience will result in less plow skips, hence better protection for the cable and a shorter installation time.

6. Remotely Operated Vehicles (ROV)

Subsea trenching ROVs have been a primary tool for subsea fiber optic cable installation and maintenance for years, and although the basic philosophy for ROV trenching has changed very little in recent years, subsea trenchers are evolving. This evolution seems to be notable in two areas: electronic component advancement and increased vehicle horsepower.

Electronic technology is growing at an exponential rate, and although ROV iPad apps are slow coming, the subsea world is not immune to these advancements. The Subsea industry experienced dramatic advancements in electronic sensors and components in the last ten years. As an example, incandescent subsea lights, which in the past would burn out on deck without cooling from ambient seawater, are being replaced by smart LED housings which turn off before overheating. Trenching manufacturers, once awash with custom built control system components, are replacing one-off designs with robust off-the-shelf industrial PLC controls and software packages. ROV mounted multi-beam sonars are used in poor-visibility sea bottom conditions, giving operators better real time situational awareness. Subsea cable tracking and locating systems (CLS) have improved, giving CLS systems user friendly interfaces and increased burial detection capabilities. These examples are a small glimpse of the many advancements taking place throughout the ROV industry, and while some of these technologies are fascinating, it's important to remember that "keeping it simple" has advantages as well. Avoiding unnecessarily complex technological fads can have tangible benefits by decreasing downtime, maintenance hours and equipment repair costs.

Along with advancements in component technology, there has also been a steady increase in vehicle horsepower (HP), primarily as a means to increase burial capabilities of ROVs. Where three meter capable plows are employed, there is demand for cable trenching ROVs to match this burial capability. This requires improved burial tools and increased vehicle power. As horsepower increases to suit this need, more power becomes available to the jetting system. Large ROVs with 600 HP and higher are common place in subsea trenching applications, especially in offshore energy markets where fiber optic cables are dwarfed by larger diameter products.

Not only can these high horsepower vehicles bury deeper, but they can also cut wider trenches faster then comparable vehicles of lesser horsepower. This translates into deeper burial and decreased time on station for the customer. The capability to bury larger diameter products also allows the telecom installers to branch out into non-traditional telecom fields such as offshore wind and oil & gas markets.

Not all projects require the largest ROV's, in fact most subsea fiber optic cable installations require vehicles in the 200 – 400 HP class. Project specific requirements drive the ROV selection much as it does for the sea plow

As we look forward into the next decade, subsea electronics will undoubtedly continue to improve, and as vehicle horsepower increases in size, there will be a continued need to balance project requirements with sensible vehicle selection.

7. Remediation – A Case Study

Recently TE SubCom had the opportunity to pick up and relay a section of a cable system that had been installed by a third party contracted ship using an articulated plow. This section was reinstalled by the SubCom cable ship Durable and a fixed share 3 meter plow improving the burial by an average of 30 cm.

A review of the data shows a slightly lower tow tension for the articulated plow, which is to be expected due to the share design, along with a positive pitch of the plow. This indicates that the share was articulated clockwise (down and back) in an attempt to obtain deeper burial depth. However, as noted previously, this limits the ability of the plow to dig in when harder seabed is encountered, causing the plow to ride up, thus reducing the burial depth.

The comparison allowed us to confirm the relationship between ship speed and burial depth. The data shows that Ship A speed was 0.10 to 1 knots faster than the Durable (on average 0.76 knots faster) with a corresponding burial depth that is on average approximately 30 cm less than what the Durable and the fixed share plow achieved; demonstrating that ship speed is critical in achieving the desired burial depth in this speed regime

8. Conclusions

Selection of the appropriate vessels, marine tools and well trained crews remain fundamental to executing the intended burial program to maximize the long term cable protection.

Tools must continue to be matched to the requirements for burial depth into the seabed, water depth, and soil types. Plows capable of 1.5m depth will continue to be required on many routes. On routes where 3m burial depth is required, the industry has turned to larger, heavier, and more powerful ROVs and sea plows. Sea plow design and operation must be well understood to know their limitations and make effective use of its capabilities. In choosing between a rigid share 3m plow and an articulated 3m plow, one must consider the seabed consistency and the desired burial depth. Even with these larger and more powerful tools, proper planning and skilled operation are of the upmost importance in negotiating varied seabed conditions, and slopes.

Although there is no guarantee against external aggression damage…. employing the appropriate tools, trained and experienced crews, and capable vessels greatly increases the overall cable protection and reliability of the network.

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