

THE ECONOMICS AND BENEFITS OF CABLE MAGNETIZATION

E. Wayne Hughes, Charles L. Collins, Jr. and
George H. Seltzer
3U Technologies, LLC
11681 Leonidas Horton Rd
Conroe, TX 77304

Paul Cloutier, PhD
Innovatum, Inc.
2020 SW Freeway Suite 203
Houston, TX 77098

1 ABSTRACT

As the submarine cable industry has moved from copper to optical fibers for signal transmission, the cables have become increasingly smaller and the amount of ferromagnetic material in them has been drastically reduced. Many festooned cables are being constructed so that they contain no copper or other means for electrical signal transmission in them at all. These cables have become increasingly difficult to locate and follow underwater. While at the same time, the industry has been forced to move toward deeper depth of burial (below the seabed) and deeper overall cable burial (water depth) in order to protect these vital commerce-enabling pathways under the sea. The owners and regulators are also demanding proof positive positioning and depth verification at time of installation and during the life cycle. The net result of these circumstances has been an increase in installation times (and costs), an increase in repair times (and costs) and often non-compliance to project verification requirements.

A new technology has been developed to increase the magnetic detectability of submarine cables. Future developments will enable the utilization of magnetic coding, similar to a 'bar code', for identifying specific cables or transition features in the submarine cable system. The process uses permanent rare earth magnets to impart a predetermined magnetic signature to the ferromagnetic material (either armor or king wire) of the submarine cable. The operation is accomplished either during cable loading (for non-repeated systems) or on board the cables ship (for repeated systems) during cable laying operations. The result is a dramatic improvement in the ability to localize, locate, and follow the cable thereby increasing the efficiency inspection, verification and repair activities.

By improving the efficiency of the installation and repair operations, the overall system economics can be improved. Installation and repair timelines (and costs) can be reduced, repair solutions can be simplified, and a better-protected, more reliable submarine system can be produced. This paper will briefly describe magnetization, the magnetization process and investigate and discuss the positive economic impact that magnetizing the cable can have on installation and repair costs, as well as the impact on overall system economics. In addition, the impact and potential for future improvements in installation and repair technology are discussed.

2 UNDERSEA LOCATION TECHNIQUES

Searching for things left or lost in the sea has occupied seagoers since ships first left shore. These techniques have evolved and been refined by the forces of both Government and commercial needs. Objects on the seafloor can sometimes be detected by SONAR, video or photo equipment depending on the how accurately the object can be localized. Generally, the detection of metallic objects buried beneath the sea floor can be accomplished by acoustic means (sub-bottom profilers) or magnetic / electro-magnetic means. Sub-bottom profiling is effective for the location larger objects such as buried pipelines, which follow a determinable path and can be imaged by traveling in perpendicular lines to the object. Smaller items, however, are difficult to discern primarily due to the sensor resolution and also due to the extremely small sensor footprint of the transducer.

Typical magnetometer-type metal detectors (proton and flux-gate) have been used effectively for years as a tool

for the location and tracking of subsea pipelines and cables as well as explosive ordnance location and treasure hunting. These types of devices are limited to the location of ferrous metals and provide no capability for the direct determination of the depth of an object beneath the sensor. Indirect assessments have been utilized but provide accuracies insufficient for regulatory inspections and burial confirmation.

Undersea cables are buried as a means to protect them from the damage that arises from fishing and anchoring activities, as well as from such naturally occurring phenomena as high currents and slumping. Indeed, most estimates rank "external aggression" as the most frequent cause of undersea cable failure by a wide margin over component failure.

Cable plows were specifically developed to bury cables during the cable lay process. Plowing provides the most efficient means of burying cables in most soils. However, plows seldom achieve 100% burial over any given length; they are recognized to have depth limitations; and they cannot be used for burying repair

sections. Consequently, a variety of technologies have been used to 'fill in the gaps' and bury cables where plows either cannot or do not perform adequately. These technologies include divers, undersea tractors, jetting sleds and Remotely Operated Vehicles (ROVs). All of these supplemental technologies have one requirement in common – they must be able to locate and track a cable, whether exposed on the sea floor or buried, in order to accomplish their work.

Data from field tests of both the magnetization and location processes will be discussed. Estimates of costs to magnetize a cable system versus the savings to Post Lay Inspection and Burial and repair projects will also be discussed.

3 INDUSTRY CHANGES & TRENDS

3.1 Submarine System Design

When heavily armored coaxial cables were used, the cables could usually be tracked on their inherent magnetic signature alone. This technique did not work well on light armored or lightweight (unarmored) cables. As early as the 1970's, AT&T developed the method of injecting an AC signal onto the cable onshore and tracking the cable by following the AC signal. Until recently, the location of buried submarine cables has relied on the injection of an AC tone. Tracking coaxial cables (and now fiber optic cables) in this manner has definite limitations. Foremost, tone attenuates with the square of the distance. Another major drawback to the AC injection technique is the logistics of coordination with the cable station. Although this would seem to be a fairly straightforward operation, offshore assets frequently are required to stand-by for extended durations waiting to get the tone on the cable. Offshore assets often cost anywhere from US\$40k - 80k/day.

Later in the 70's Innovatum pioneered the utilization of magnetometers to track buried pipelines and power cables.

As submarine telecommunications cables have become smaller and lighter, the ability to track them has become increasingly difficult. The advent of fiber optic technology in undersea cables drastically reduced the diameter (and the overall cross sectional areas of armor) of the cables, making them inherently more difficult to track using passive tracking technology.

To overcome this difficulty, a variety of new technologies were implemented. Among these technologies were tracking the DC power signal that resided on the cables to power the repeaters and 'pulse induction' methodology whereby a signal is emitted from a source nearby the cable to 'excite' the cable and the returns from this 'excitation' are sensed to determine cable location. Several acoustic (sonar) methods have also been tried, but most have been shown to have only

limited success and unlikely to meet the accuracy needs of the industry.

At the same time the cable industry has moved to smaller more delicate cables and changes in the fishing industry continue to pose significantly greater threats today than in the past. With the reduction in catch at shallower depths, fishing activities have moved to progressively deeper waters. Additionally, cable damage has been reported to occur at depths heretofore thought improbable. Reports of damaged cable by fishing activities in 1500m water depths are becoming common. In soft bottom areas, damage has occurred to cables buried 3m and deeper. The consequence is that cables are being buried deeper into the seabed and in much deeper water than in the past. Cables were once believed to be safe if buried to at least 0.6m below the seabed down to 1000m; the present industry practice is to bury to 1.0+m (moving toward 1.5m) in water depths to 1500m. In some extreme cases, cables have been buried over long distances to 4+m. There is also an emerging trend to demand more rigid requirements on Post Burial Inspection and verification to ensure that the cables are, in fact, buried as specified throughout the area where they are thought to be at risk.

The recent surge of new high capacity regional and domestic festoon systems present additional challenges. Since unrepeatered systems have no need for power conductors, the ability to inject an AC tone on these cables is severely limited. In addition, festoon systems tend to be installed along the coast where fishing activities are often the greatest and where the burial requirements are the most pronounced.

3.2 Submarine System Installation

The implementation of fiber optic technology and the ongoing development of higher data densities through the advent of DWDM has meant that the financial impact of cable failures to the system owner continue to increase. New high capacity systems are being designed with different types of specialty fibers at discrete locations between repeaters. In a repair scenario, it is critical to be absolutely certain of the location of the splice between the amplifiers and the type of fibers that the cable contains.

The tremendous increase in the number of submarine cables being installed around the world coupled with the reluctance of regulators to issue additional landing permits has resulted in crowded shore approach corridors and shore landings. Where there once may have been only one cable coming ashore to a beach manhole, multiple cables in a 'narrow cable corridor' is now becoming the norm. Near shore cable failures now require the surgical extraction of a single cable from among the many, so grappling is no longer an option.

Accurate placement of cables in and around sensitive seabed biological and geological features is becoming a critical concern worldwide. Another trend is legislation requiring that cables be recovered and removed at the end of their useful life.

Clearly, the ability to more quickly locate, track, and pinpoint specific areas along a cable would result in shorter installation timelines, shorter repair timelines, and more profitable, more reliable systems. The Innovatum Cable Magnetizer has been designed to meet this emerging industry need.

As shore landings become more densely occupied, the ability to install cables closer together, identify buried cable and more accurately report on cable position and depth of burial will become significantly more important to cable system owners and installers.

4 MAGNETISM – BASIC CONCEPTS¹

The fact that iron can be magnetized has been known for thousands of years, but the explanation of this phenomenon has awaited the recently acquired knowledge of atomic structure. It has been shown that microscopically small regions, called domains, exist in iron and other ferromagnetic substances. In a piece of unmagnetized iron, the directions of the various domains are arranged in a random manner with respect to each other. Unmagnetized undersea cables exhibit this phenomenon – with widely varying magnetic field strengths and orientation along their length.

By exposing the iron (cable) to sufficiently strong field strength, all of the domains rotate into parallelism with the field. Magnetism that is retained for long periods without appreciable reduction, unless the material is subjected to a demagnetizing force, is called permanent magnetism. Imparting permanent magnetism to the cable is the goal of (and, in fact, the result achieved by) the Cable Magnetizer.

5 THE INNOVATUM CABLE MAGNETIZER

5.1 The Concept

The Innovatum Cable Magnetizer (Figure 1) is a patented system that uses specially configured, rare earth magnets to impart a varying, unique, permanent magnetic signature to the ferromagnetic material in a cable. This system greatly enhances the ability to track

cables and does not rely on exotic tracking equipment or techniques. From a practical point of view, a single armored (SA) cable that has been magnetized has a magnetic field strength similar to a 150mm (6 inch) diameter pipe whereas a magnetized double armored (DA) cable has a resultant field strength similar to a 300mm (12 inch) diameter pipe.



Figure 1: Innovatum Cable Magnetizer

The Innovatum Cable Magnetization System significantly increases the magnetic field of the cable's armor or strength member. The magnets used in the magnetizer are rare-earth magnets with pole strengths of approximately 20,000 Gauss and are similar to magnets commonly used in motors and generators. This enhanced magnetic signature can then be tracked without the need for an active injected tone. The magnetization process can be completed during the lay operation, while the cable is loaded onto the vessel, or during manufacture depending on the system design. This enhancement is permanent (assuming that stress on the cable does not exceed the elastic limits of the ferromagnetic material) and in no way harmful to the cable. Even if the stresses on the cable do exceed the elastic limits of the ferromagnetic material, the magnetization of the cable is still permanent. The natural de-magnetization of the cable material is a very slow process with a time scale measured in centuries.

The magnetization process cannot be completed prior to loading onto the vessel when used with *repeated systems*. The reason for this is that powering the system while in the cable tank is believed to effectively

¹ From AMERICAN PRACTICAL NAVIGATOR; Bowdich, 1984, DMA, Washington

demagnetize the cable, however, testing is underway to ascertain the validity of this supposition. Therefore, the magnetizer device is designed for ease of use on the back deck of a cable ship. The Cable Magnetizer is packaged such to easily accommodate the layout of any cables. A frame holding the magnetizer maintains contact with the cable as it passes and is also designed to be easily removed from the cable highway in order to allow repeaters and splice boxes to safely pass.

Unrepeated (unpowered) systems can be efficiently magnetized when the cable is being loaded onto the ship at the cable factory, at the depot or during the lay process. Again, the magnetizer is designed to allow it to be lowered out of the path to pass splice boxes.

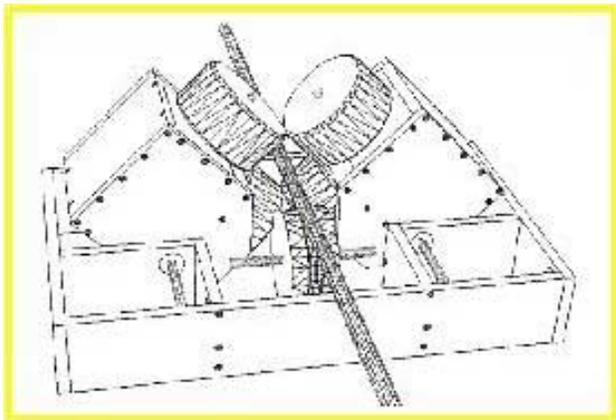


Figure 2: Magnetizer schematic

Figure 2, above, shows the basic design of the magnetizer device and the positioning of the magnets themselves. The magnetizer is designed to be adaptable to the many configurations and requirements of cable owners, cable installers and cable ships.

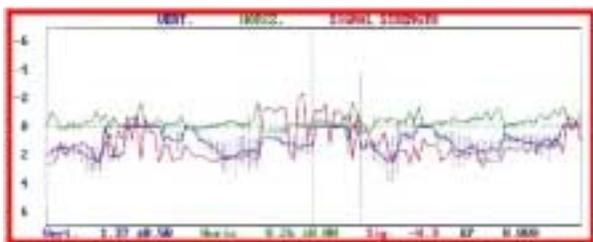


Figure 3: Random signal from unmagnetized cable

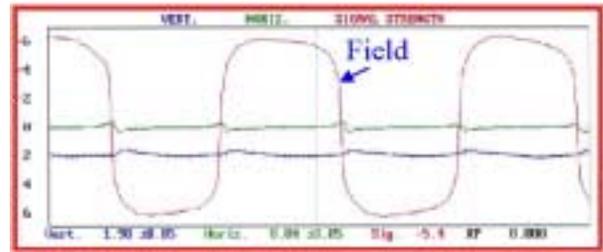


Figure 4: Signal from magnetized cable

The graphics shown above in Figures 3 and 4 show the difference between the magnetic signature of an unmagnetized cable and the signature of a magnetized cable. In the event of a cable break or overstressing, the signal from a magnetized cable will not lose its unique signature, however, the signal frequency may change, that will facilitate expeditious location of the break.

Another advantage of the magnetization process is that data can be embedded within the resultant magnetic signature, much like a bar code. This unique imprint can allow installers, utilizing the INNOVATUM ULTRA, to identify specific cables at crowded shore endings, thereby avoiding inadvertently cutting the wrong cable during repair operations. This encoding feature also allows for marking the cable with a number of other significant data such as crossings, KP's, AC's, and cable and fiber transition points. The graphic above shows the magnetic signature of a cable with data embedded.

This *unique* signature, shown in Figure 5, allows for accurate cable tracking and depth verification during Post Lay Inspection and Burial (PLIB), rapid cable location for cable repair work, and discrimination among nearby cables.

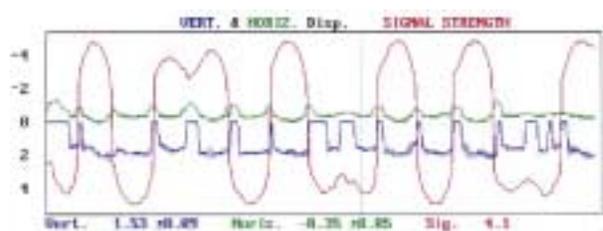


Figure 5: Signal from magnetized cable w/ data encoded

The magnetization process benefits any tracking system that uses magnetic field gradients as the basis for cable tracking. The Innovatum Ultra system, however, was designed with tracking algorithms specifically optimized for passively locating magnetized cables as well as accurately determining the depth of burial for these cables. The Ultra System is also the only system capable of simultaneously operating in all known

tracking modes: passive magnetization, active AC (tone), active DC, and pulse induction.

The magnetic fields induced on the cable by the magnetizer have no effect on fish, sharks, whales, turtles or other marine life. There has been some evidence that sharks avoid large, steady magnetic fields associated with large DC electric currents but the levels associated with the artificial magnetization of cables are considerably below those levels.

5.2 Proven Field Experience

The INNOVATUM cable tracking system has been a standard within the oil industry for more than 20 years. INNOVATUM has magnetized over 2000 kilometers of cable and pipeline as of January 2001. Cable systems currently benefiting from enhanced magnetization include a deepwater, powered system owned by the US Navy and the Concerto 1 (installed by Flute, Ltd, now part of the Interoute i-21 network). Concerto 1 is an unrepeatable submarine and backhaul network system in the North Sea.

6 ECONOMICS

The economic benefits that can be derived from the ability to more effectively locate, track, and pinpoint specific areas on cables will vary from cable system to cable system, but they can be broken down into 3 categories as shown below:

- Installation Cost Savings
- Repair Cost Savings
- Improved System Profitability

Installation cost savings refers to reduced installation costs achieved through more efficient burial and as-built survey operations and are net of the cost to perform the magnetization process.

More importantly, if PLIB operations delay the RFS date of the system the economic impact as a result of lost revenues to the cable system owners can be tremendous. Magnetizing the cable can result in much faster PLIB rates than can be achieved on a passive cable. The most significant impact on system economics is the potential improvement in the RFS date as a result of reduced PLIB time attributable to magnetizing the cable.

As previously noted, the actual numbers vary from system to system but are indicative of time savings that are possible. The point is that the sooner a system comes on line, the sooner traffic starts flowing, and the sooner revenues begin. Similarly, cost savings can be

achieved during repair operations that result in net cost savings and reductions in downtime.

7 FUTURE DEVELOPMENTS

One of the enhancements for this technology currently in process is a universal ROV deployed skid for magnetizing existing surface-laid cable systems.

Another is a grapnel sensor package to indicate the approaching cable and a "smart" cut-and-hold grapnel that will use the magnetic signature to key its actuation.

8 CONCLUSIONS

Magnetizing subsea fiber optic telecommunications cables will provide substantial benefits to the system owner, the installation and/or repair contractor. Magnetizing cables provide the following benefits:

- Reduces time required to locate buried cable, for:
 - Post Lay Inspection (X-Y position and accurate depth verification),
 - Post Lay Burial (PLB),
 - All PLIB - both incident to installation and future, during life cycle,
- Provides ONLY means to locate and verify deeply buried cables (1 – 5+ meters),
- Eliminates AC toning requirements,
- Enhances cable location for future cable crossing surveys and installations,
- Provides ability to locate out-of-service cables for end-of-life removals.
- Possibility to shorten RFS schedule.

THEREFORE, cable magnetizing provides cable owners, permitting authorities, and governing bodies with PROOF-POSITIVE verification of both as-laid cable location and actual burial depth at any time during the life of the cable. Net installation and repair cost savings are also expected.