CABLE PROTECTION METHODS AND APPLICATIONS IN AN ARCTIC ENVIRONMENT

Ryan Wopschall (Fugro Pelagos, Inc.), Klaus Michels (Fugro OSAE, GmbH)
Email: rwopschall@fugro.com

Fugro Pelagos, Inc., 1200 Westlake Avenue North, Suite 803, Seattle, WA USA 98115

Abstract: Cable protection methods and applications are going to become an increasingly important aspect for the protection of future cable installations in the Arctic environment. Protection methods have implications on installation procedures and logistics, levels of acceptable risk of cable damage, and maintenance and repair logistics and timeframes. While each of these parameters is an important consideration for the planning of Arctic cables, the specific environmental parameters within various regions of the Arctic should also be considered.

The largest and relatively unconstrained risk to cables in the Arctic is the impact of ice. Whether in the form of deep iceberg scouring, fast or landlocked ice, pressure ridges, or ice dynamics during the annual melt and freeze cycles, ice risk will largely define cable protection methods as they apply specifically to the various ice risks present.

1. THE ARCTIC – A GEOLOGIC SETTING

Most landing sites in Arctic areas are on low-lying shorelines that are comprised of alluvial sediments and glacial till consisting of a mixture of sand, pebbles and cobbles in a variety of stratigraphic distributions. A few areas have rocky shorelines with significant relief, though this is a less common characteristic, especially for locations where a submarine cable would be considered to touch land.

Landings in the northern latitudes of the Arctic have shallow permafrost under the shallow seafloor, as well as on land. Permafrost is soil that has been at or below freezing for an extended period of time, generally more than two years. This type of soil condition can mimic bedrock or an otherwise very stiff soil that is hard to penetrate or displace.

Another characteristic of the Arctic setting is that the global sea level is rising and is driven by global warming. This problem is exacerbated by melting permafrost which causes additional loss of elevation at coastal areas. As a result, beach landings for Arctic submarine cables will need to be designed with additional safety allowance for rising sea level and melting permafrost.

2. ARCTIC ICE

In all Arctic areas, the risk of scouring of the seafloor due to ice ridges or pressure ridges in the sea ice is significant. Ice ridges build up during the winter as ice accumulation increases, often locking itself to land and deforming from pressure in a way that creates ridges that can extend tens of meters above the sea and even moreso below the sea surface. Recent scours in the Arctic occur in water depths up to 60 meters and can penetrate the seafloor 1-1/2 to 2-1/2 meters. Scouring tends to run parallel to the seashore following predominant ocean currents. Though pressure ridges form throughout the winter, scouring doesn’t usually occur until the spring when ice melts out and becomes mobile.

The keels of occasional icebergs can extend into deeper water and cause deeper scours, but icebergs are generally only a significant threat in the Labrador Sea, where they are drifting down from disintegrating glaciers calving off Greenland.

3. ICE RISK TO SUBMARINE CABLES

Significant studies of ice risk relating to oil and gas infrastructure (pipelines) have been conducted through numerous working groups over the last thirty years. These have been in the form of marine surveys and repeat marine surveys in the Arctic, predominantly on the Grand Banks and off the North Slope of Alaska, as well as laboratory and computer simulations and analysis for various ice risk scenarios. From these findings it is apparent that there is a significant difference between the occurrence of old ice scour events (ancient or paleo-scours dating to the last glacial maximum) and recent ice scour events. Therefore, one of the only methods of quantifying the risk of recent ice scour events is to repeatedly survey (seasonally) an area in order to map the occurrence, frequency and distribution of scours. Such work is rarely completed for the sake of cost and interest. Therefore, other parameters have to be relied on to determine ice risk.

Laboratory studies have shown that the penetration of ice into the seabed can cause a deformation up to twice the depth of penetration. Therefore, if an ice ridge scours the seafloor down to a depth of 2 meters below the seafloor, the actual soil deformation will be up to 4 meters below the scour and can cause enough force to damage submarine infrastructure. This parameter alone has significant implications on how deep a submarine cable should be buried below the seabed.

Additionally, scours may not pose a threat to a singular point along a submarine cable, but can exist for hundreds of meters along the seabed as ice is dragged by currents and other forces. Therefore the risk to a submarine cable may also be one of dragging and faulting rather than just pressure or deformation at a point.

4. SUBMARINE CABLE BURIAL DEPTH

The most significant question related to the protection of submarine cables in the Arctic environment is how deep should a cable be buried below the seabed and to what water depth should the cable be buried.

As mentioned in the previous section, over thirty years of studies have been conducted in the oil and gas industry on the Arctic environment. Though there is a large variation in both study methods, results and geographies, an analysis of such studies can reveal commonalities that can be applied to the submarine cable industry.

Generally speaking, ice risk can exist down to a water depth of approximately 50 meters with scour depths ranging from 1-1/2 and 2-1/2 meters. Though sub-gouge deformation can affect up to twice the scour depth, it is generally accepted that some sub-gouge deformation can be tolerated by submarine infrastructure. Though the amount a submarine cable can tolerate sub-gouge deformation has not be quantified, it can be assumed that a submarine cable is a flexible (non-rigid) structure and can deform under pressure within some allowable tolerance. Therefore, it may not be necessary to assume a submarine cable needs to be buried at a depth of twice the deepest scour

(5 meters). Rather it can be assumed that a lesser burial depth would be adequate. Therefore, a burial depth of approximately up to 3 meters below the seabed could generally be considered adequate in the Arctic environment.

As for water depth, studies have revealed recent scours to predominantly affect areas ranging from < 10 meters to up to 30 meters water depth with some scour occurrences as deep as 60 meters. Therefore, as a general recommendation, submarine cable burial should be considered to at least 50 meters water depth in most areas.

5. SUBMARINE CABLE PROTECTION METHODS

The preferred way to protect nearshore cables in the Arctic will be by use of horizontal direction drilling (HDD) which will allow the cable to be run to significant depths below the seafloor. HDD boreholes can be drilled through alluvial sediments as well as rocky sub-bottom and permafrost areas. HDD is difficult in areas where large pebbles or small boulders exist which can move or collapse around the drill pipe.

HDD can extend as far as 2 kilometers offshore, but it is prudent to assume that the borehole will need to come to the surface at about 1,500 meters from the start of the borehole. In some areas HDD may get to water depths that are greater than 40 meters where the risk of scour decreases, but in many other areas these water depths are further offshore. In these cases it will generally be prudent to bury the cable, generally by post-lay jetting, to wather depths of around 50 meters. As mentioned in the previous section, the cable should be buried up to 3 meters below the seabed to protect from scouring. Given the remote location of many of these landings, if the cable cannot be buried by plowing during original installation, it is likely that the most economical way to conduct post-lay burial will still be to use the primary cable installation vessel rather than to bring in another vessel.

The biggest problem for the implementation of HDD in the northern Arctic areas will be the cost of mobilization of the equipment. The equipment is bulky, comprised of the drilling platform, the inventory of drilling pipe needed, and ancillary generators and pumps and tanks for holding drilling mud and water for flushing the system.

The HDD equipment is generally shipped to the landing area. Since there are limited ports in the Arctic, the HDD equipment could be brought to a landing site on a large barge with a folding front platform (such as a military landing craft) that can be dropped onto a beach or riverbank for loading and unloading of the HDD equipment.

An alternative way to mobilize the HDD equipment is to transport the entire kit aboard a C-130 aircraft that is flown to a nearby landing strip. This has been successfully done in northern Canada. There are landing strips near all the potential landing sites in Canada and some of these potential candidate airports are likely to be just cleared regions that are flattened and generally covered with gravel. A suitable C-130 can operate in these conditions. Air transport of the HDD equipment is likely to be the most economical mobilization.

In practice, the most economical procedure for the HDD installation is to leave the drilling pipe (which has an inside diameter of about 95 mm) in place and then run the cable through the fully extended drill pipe. For reference, a typical double armor cable has a diameter of 45-50 mm, which would fit in the conduit.

6. REFERENCES

[1] G. Sonnichsen, T. King, I. Jordaan, C. Li, "Probabilistic Analysis of Iceberg Scouring Frequency Based on Repetitive Seabed Mapping, Offshore Newfoundland and Labrador", 18th International Conference on Port and Ocean Engineering Under Arctic Conditions. Vol 1 (2005) 85-94

[2] S. Kenny, R. Phillips, J. Clark, A. Nobahar, "PRISE Numerical Studies on Subgouge Deformations And Pipeline/Soil Interaction Analysis", 18th Conference on Port and Ocean Engineering Under Arctic Conditions, Vol. 1 (2005), 43-52

[3] K. Croasdale, "Investigation of Ice Limits to Ice Gouging", 18th International Conference on Port and Ocean Engineering Under Arctic Conditions. Vol 1 (2005), 23-32

[4] A. Marchenko, "Forming of Seabed Scours by Tidal Drift of a Floe Joined to Grounded Ice Ridge", 18th International Conference on Port and Ocean Engineering Under Arctic Conditions, Vol 1. (2005), 53-64

