RISKS TO SUBMARINE CABLES IN THE ARCTIC

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Abstract: Arctic submarine telecommunication cable routes are becoming increasingly attractive as an alternative to established transcontinental routes. There are some risks posed to cables installed in arctic regions unique to the icy environment. The route engineering risks posed by the arctic environment and some potential methods of risk mitigation and cable protection are discussed.

1. INTRODUCTION

There are many sources of damage for submarine cables and there is a large body of work which discusses the most common risks encountered along the world's established routes between major population centres.

This paper describes the risks posed to cables laid in arctic regions unique to the polar environment and offers some potential methods to protect submarine cables from these risks.

The current clear trends in decreasing arctic sea ice extents have encouraged a recent re-appraisal of the feasibility of cable projects in the arctic region.

Several desk based studies have been carried out for new pioneering projects. Experience from the relatively small number of existing cable systems in high latitudes has provided important input into project risk assessments. In 2003 Global Marine Systems Ltd installed a cable system connecting Norway to Svalbard. The landings in Longyearbyen, Svalbard were at a latitude of 78° N, the most northerly commercial fibre optic cable in history.

Alongside the few existing high latitude systems, the risks to offshore oil and gas pipeline projects have previously been studied in arctic conditions and these studies provide useful references.

2. ADDITIONAL CABLE SAFETY RISKS TO CABLE PROJECTS IN ARCTIC REGIONS

i) Sea Ice Pressure Ridges – Frozen sea ice forming sheets covering the sea surface are common in the arctic. A feature of sea ice sheets are pressure ridges. These ridges form as pressure on the ice sheets causes them to deform. The sheets fracture and the forces applied to the edges break up the ice. Figure 1 shows an ice ridge landscape in the arctic. The broken ice is forced over and under the ice sheet forming ridges or hummocks with surface pile up (sail) and subsurface keels. Figure 2 shows the profile of a computer simulated pressure ridge formation. Note how much further the subsurface keel extends below the ice sheet compared to the protruding surface ice above.

If the depth of water is less than the draft of the keel, the keels will interact with the seabed as the ice moves. A keel dragging over seabed surface sediments will form a typical elongated groove termed a scour or gouge. The course of these scours varies dramatically, some straight, others meandering, with big variations in distance.

These seabed scours have been imaged using sidescan sonar and the dimensions measured by multibeam echosounders. On the Beaufort Shelf, Alaska ice gouges by pressure ridge ice have been found with incision depths from 20cm to 5.5m, the maximum number occurring at the 20m isobath and the deepest at 45m. [1]

In the Bering Sea, density of ice gouging is 60 times higher in the 10m-20m deep zone than in 5m-10m or 20m-39m deep zones. [2]

Figure 1 An Ice Ridge Landscape (courtesy of Prof H Eicken)

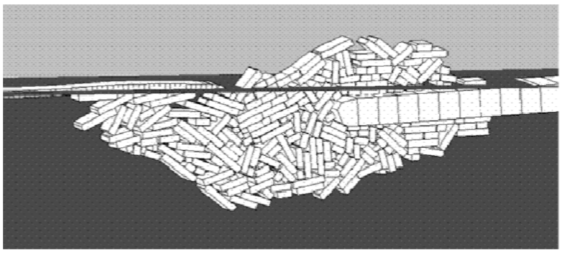

Figure 2 Profile of a Pressure Ridge Simulation

First year ice scouring can be in single grooves or multiple raking of the seabed. Single grooves can commonly be 15m to 25m wide, extending up to 100m or more where multiple grooves occur. Typically depths of 0.25m to 0.5m are observed, although they can be down to 1m. Estimates suggest that in water 10m to 20m deep nearshore gouges average 21cm in depth and are generally less than 1m deep [3]. These depths may be a conservative estimate due to later sediment infill.

Around the arctic coast shorefast ice can occur. This is ice supported by the coastal landmass and does not break up as readily as the offshore pack ice. Moving pack ice can collide with stationary shorefast ice to develop ridges. These ice shear zones form a region where gouging can be prevalent.

Inshore of the shear zone gouging is rare, because shorefast ice is relatively static and protects inshore areas from consequential ice gouging. [2]

In summary, ice scours occur where a combination of the presence of the right sea ice conditions and shallow enough seabed depths occur.

An ice keel's interaction with the seabed poses a real risk to submarine cables. As the keel gouges the seabed it may come into direct contact with the cable. Whether cables are surface laid or buried, if the keel penetrates to the cable level, the keel may crush it, damaging the protective layers (armour wires and insulation) and the electrical conductor or optical fibres. The keel may drag the cable, placing excessive tensile forces on the cable, similarly causing damage to the cable. Even protective cable ducting solutions designed to offer additional protection may fail under the extreme forces applied by ice. [4].

To compound the problem, if the cable is dragged off line from the installation route by a keel, it could be harder to locate during a repair operation.

As described earlier, the gouging often occurs in shallow water and the resulting repair solution may be a replacement shore end. A shore end is more complicated and resource intensive than a simpler vessel based repair operation and undertaking it in the arctic increases the complexity.

ii) Coastal Ice Pile Up - Ice pile up on the coastline is similar to the ice sheet break up at pressure ridges, but instead of forming a keel and a surface pile, the ice is forced to ride up the coastal shoreline or a coastal structure. The broken pieces of ice can form a large disordered pile which can pose a significant risk to coastal infrastructure and buildings close to the shoreline.

The conditions for ice pile up occur most often during the spring ice breakup season. At this time shorelines can lose the protection provided by a shorefast ice margin and a periphery of open water can be created. If this is combined with a detached main sheet and the driving force of strong winds or currents and there is enough open water for the sheet to build sufficient momentum, ice pile up and coastal ice ride up can occur.

An example of a pile up event took place in Kotzebue, Alaska, in May 2011, when the ice piled up on the coast road and spread towards the town dwellings. A picture of the pile up is shown in Figure 3. The initial pile up event was very rapid, lasting only 5 minutes and captured by a local townsperson on video. [5]

Figure 3 Coastal Ice Pile Up Kotzebue, Alaska May 2011

Cables are potentially at risk as the ice is forced up the shoreline and gouging of shore material occurs. If the cable is not sufficiently protected and the ice reaches it, damage from the large ice forces may result.

Another risk to cable projects from coastal ice pile up is the threat to cable infrastructure facilities. For instance, cable landing stations (CLS) sited too close to a coastline at risk may suffer damage from the ice. Figure 3 at Kotzebue, Alaska illustrates well the potential for damage to coastal infrastructure.

For pressure ridges and ice pile up the extents of seasonal sea ice and local conditions will determine if a threat to cables exists. Sea ice seasonal limits vary each year. The trend in recent years is undoubtedly towards less ice coverage in the arctic, both a contraction in the maximum and minimum extents. The cause of this trend is widely attributed to global climate change.

Figure 4 shows the minimum bi-annual ice extents limits for 2002 to 2012 [6]. The general trend is towards less ice cover, however future years will continue to show variations in the ice extents. Therefore assessment of the risks from ice to cables should take into account these annual variations.

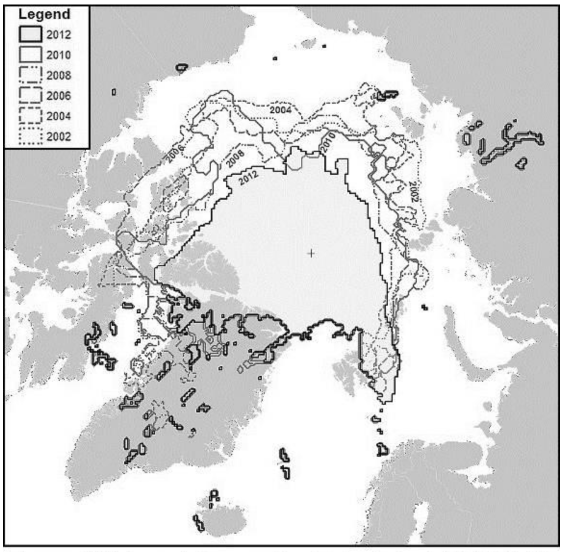

Figure 4 Minimum Bi-annual Ice Extents Sept (2002-2012)

iii) Icebergs and Bergy Bits – Icebergs originate from glaciers or ice shelves and are formed as huge pieces of ice calve from the glacier or shelf. These huge fresh water bergs are then carried by currents and winds across the sea until they eventually melt away. Bergy bits are small icebergs in the latter stages of melting or iceberg fragments, typically rising up to 4m out of the water.

As icebergs migrate on the open sea, in a similar manner to pressure ridges they can ground on the seabed causing gouges or scours. Iceberg keels are far larger and have deeper drafts than pressure ridges and scours have been recorded up to 170m water depth on the Grand Banks of Newfoundland. [7]

An illustration of the characteristics of a single keel ice gouge is shown in Figure 5. [8]

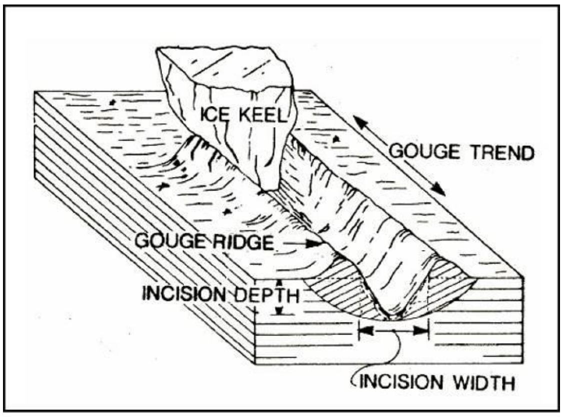

Figure 5 Illustrated Single Keeled Ice Gouge Characteristics

In the arctic the major source of icebergs is the glaciers in West Greenland. Icebergs calved from these glaciers generally drift northwards into Baffin Bay, and then turn southwards and extend right down to the Grand Banks off Newfoundland. Figure 6 shows the common arctic iceberg tracks [9]. This process can take 2 to 3 years and only a few icebergs make it, many disintegrating en route. The average drift rate is 0.3 knots but can reach 1.4 knots once they reach the Gulf Stream.

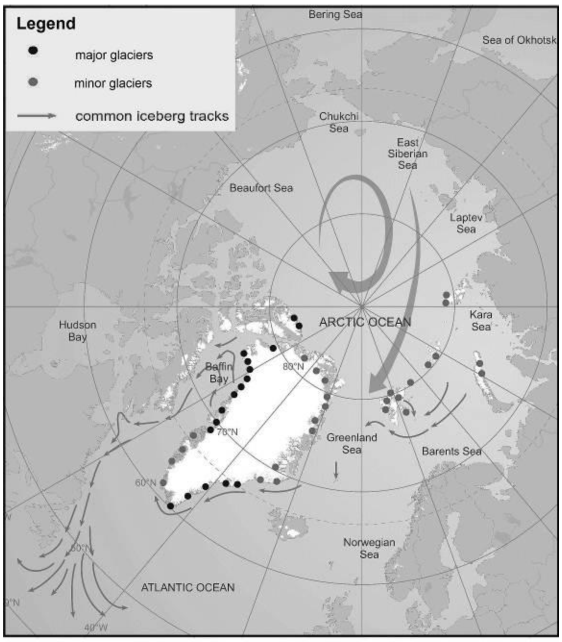

Figure 6 Arctic Iceberg Tracks

iv) Strudel Scour - Strudel scour occurs seasonally in spring in near shore zones near to river courses. Fresh meltwater flows to the sea and out over the surface of frozen shore-fast ice. Cracks and holes in the ice allow the head of fresh water to flow down beneath the ice sheet. The velocity and volume of water through the holes and cracks can be so great it can cause water jets which scour seabed sediments in shallow areas. Recent monitoring of strudel scour depressions in the Beaufort Sea [10] revealed scours up to 70 meters horizontal dimension, and 2.3 meters scour depth between the years 2005-2006. Figure 7 shows the strudel scouring process.

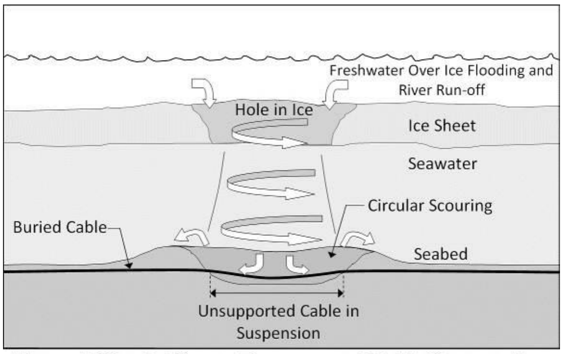

Figure 7 Strudel Scour Process and Cable Suspension

Unlike the risks discussed earlier, the risk from scouring is indirect. Where cables have been buried, strudel scour may reduce or eliminate the depth of cover, leaving the cable more susceptible to other direct risks such as trawl fishing or anchoring. If the scour is deeper than the cable burial depth, a cable may become suspended. If the scour location is subject to tidal currents and wave action this could lead to strumming. Strumming has the potential to damage a cable through abrasion. At this time strudel scour risks are untested and their real significance is unknown.

There are many limitations on strudel scouring. Distribution is linked to the locations of river courses, and the offshore range of spring overflooding. Other factors include the depth of overflooding fresh water, which will affect the strength of the water jets, and the depth of the seabed.

As the depth of water increases the strength of the jets reaching the seafloor will decrease. Hard seabed sediments will offer resistance to scouring and the shorefast ice can sometimes reach to the seabed (bottomfast ice), preventing drainage.

v) Increase in Coastal Erosion – The reduction in ice limits shown geographically in Figure 3 have a consequential effect on coastal erosion rates. The huge increase in open water areas and lengthened periods these areas remain ice free increases the fetch length upon which storm events can act. Some models of the arctic climate predict stormier autumn and winter seasons, which could exacerbate this issue.

The increase in air and sea temperatures combined with higher energy of the waves acting on the coast have resulted in increasing coastal erosion rates. These have been studied and reported in the Alaskan Beaufort Sea region where erosion rates have doubled from $0.48 km^2\ yr^{-1}$ during 1955–1985 to $1.08 km^2\ yr^{-1}$ during 1985–2005. [11]

Unhindered coastal erosion will alter the coastal profile dramatically, potentially exposing cables buried during original installation. Site selection for beach manholes and CLS should consider prevailing wind directions, coastal geology and the risk of structural destabilisation by erosion.

3. SUGGESTED SOLUTIONS

There are many ways to reduce the risks to cables installed in the arctic.

i) Routing Decisions – A first principle of good route engineering is to avoid or limit the exposure to areas where risks of damage to a submarine cable system may occur.

For the arctic risks from pressure ridge keels, iceberg keels and strudel scours this means favouring deeper water where possible and routing the cable in water depths beyond the shallower risk zones.

ii) Site Selection – Selection of landing sites can be critical, as once chosen they become a constraint for the offshore routing discussed in (3.i). In addition to normal site selection factors, arctic cables need to assess the risk from ice ride up and pile up, and the general trend of increasing arctic coastal erosion rates.

Research into historical events, study of ice conditions, currents, local weather and a careful assessment before selecting locations for new facilities such as manholes and CLS buildings is advised. Much of this work will commence during desk top study and site visit activities.

iii) Cable Protection Options – The most common and effective way to protect submarine cables is to bury them in the seabed. Where seabed sediments are conducive to burial, cables can be protected from ice scouring by burying to below the depth of expected scour troughs. The efficacy of such solutions must be evaluated against the burial tools available and the shallow seabed geological conditions.

Burial is not an effective option if areas of seabed are too hard to bury using available tools and are expected to feature grounding pressure ridges or bergs.

The use of protective ducting is a common method of adding additional protection to a cable especially crossing the shoreline and near shore environments. Ducting comes in many forms. The duct materials vary, with plastics, steel, ductile iron and cast iron used. The cable can be placed in a pre-installed duct, or the duct applied afterwards using articulated piping.

Horizontal direction drilling (HDD) is an excellent solution for pre-installed ducting and the depths achievable below the surface enables the cable to be housed below the risk level from shore and near shore ice risks. HDD solutions for telecoms cable landings are a large topic, and there are many considerations such as the mobilisation of specialist equipment to often remote arctic locations, geotechnical conditions and drilling lengths required versus drill rig size.

Ducting on the surface is potentially at risk from ice risks such as scouring [4]. Placing the cable and protective system below the risk level in the seabed appears to be the key to effective protection.

Cable armouring has been and is an effective method of protecting cables against many risks found around the world but the forces applied by large ice masses may render armouring a less effective option against the particular risks from major ice events. Cable armouring remains a good way to improve resistance to other risks and will undoubtedly improve the robustness of the cable when faced with minor ice events.

iv) Route Diversity and Configuration – As a way of reducing the overall risk to connectivity in a system, diversity and configurations improving redundancy are key decisions. If end to end traffic has priority over resilience at every landing, a branch and spur solution may be preferred. If retaining maximum connectivity to all landing locations is the main aim then physically diverse double cable landings and a festoon design may be preferred.

4. CONCLUSIONS

Some arctic submarine cable projects have been successfully installed, others have provided a useful insight into the unique challenges and possible solutions.

By clearly identifying the arctic risks to submarine cables, the telecoms industry will hopefully be better prepared for future projects.

The technical means to reduce risks are available to the cable industry but the careful study of the project route initially through desk top study and site visit activities is essential. Done well, these activities will ensure key project decisions at an early stage are made on an informed basis and lead to a well-engineered and crucially, a reliable cable system.

The Svalbard system, currently the most northerly submarine cable in the world since installation in 2003 at a latitude of 78°N, remains fault free and is an example of how well engineered and installed cables are a practical proposition in Arctic regions.

The strudel scour risks described are a somewhat unknown quantity for cables, however for completeness this topic has been included, as possible conceivable scenarios may make it significant.

The risks considered are strictly related to cable engineering, and clearly many other project risks will be encountered in the arctic environment. These other risks will have at least as big an impact on project implementation.

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