PROTECTION OF GREENLAND CONNECT LANDFALL IN ARCTIC WATERS

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Abstract: This presentation addresses the project on Horizontal Directional Drilling (HDD) of tunnels to install 5”conduits from the beach man hole out to 200 meters of water depth and make new landfalls to the Greenland Connect Submarine cable beneath the bed rock. Greenland Connect is a submarine cable project connecting Greenland to Europe and North America, providing Tele Greenland backhaul traffic from landing sites in Iceland and Newfoundland to London and Halifax. Moreover Greenland connect is offering carrier customers transit from Europe to North America.

Greenland Connect was commissioned in 2008 and in commercial service from 2009. . Greenland Connect has since its installation on 4 occasions been damaged by glacial ice stranding on top of the cable during its natural passage through the Godthåb fjord. All 4 encounters have caused damage close to the shore in shallow water.

The only efficient solution to protect the landings was found to be Horizontal Directional Drilling of both landfalls in two tunnels to keep physical separation and redundancy. Presentation describes a summary of the Greenland Connect project, scope of work covering the protection program; wet seismic survey, undertaking of the drilling work and finally the marine operation. All work has been completed successfully in November 2012. This operation is as far as Tele Greenland is informed the deepest HDD operation and landfall ever made, the longest, and even undertaken in the most hostile environment with high tidal currents, cold temperatures and ice.

1 SUMMARY OF THE GREENLAND CONNECT PROJECT

In 2006 Tele Greenland’s management team presented the “Greenland Connect” prospect to the management board. Greenland Connect is a submarine cable project connecting Greenland to Europe and North America. The solution is based on a 20 year long backhaul agreement providing Tele Greenland backhaul traffic from landing sites in Iceland and Newfoundland to London and Halifax, where interconnect and IP peering can be traded at market conditions. The submerged cable system was planned as an amplified dual fiber link with the capacity of 2 times 128 wavelengths of 10Gb/s. Landing stations are established in Landeyersandur near Vest Manna Islands in Iceland, Qaqortoq, Nuuk in Greenland and Milton in Newfoundland. Landing sites accommodates high voltage power supply systems for the submerged optical amplifiers and transmission equipment for the DWDM- system. Tele Greenland’s financial position is strong and allowed for 100% company ownership and the business case has positive NPV in a less than 20 year time span. Commissioning of Greenland Connect in March 2009 has brought Greenland’s technology status up from a satellite based backhaul with long latency and low speed to modern telecommunications quality similar to Europe and USA. Hence traffic volume has been growing with the same market trend as the business experience in all other modern societies.

2 CABLE DAMAGES

The system has been performing as expected and very few errors have occurred in the land based equipment. The system has not suffered any errors in the wet segment, besides the 4 occasions addressed in this article. Greenland Connect has since its installation been damaged on 4 occasions by glacial ice stranding on top of the cable during its natural passage through the Godthåb fjord. All 4 encounters have caused damage close to the shore in shallow water. During the desk survey and wet survey, several candidates for landing of all segments shore ends, were analysed thoroughly and conclusion was that the two Nuuk landings were the best alternative. However reality shows that the landfalls have been damaged 4 times due to external aggression from glacial Ice. First incident was in the winter 2009 and had no customer impact since it happened before system was taken into active services. 3 other incidents happened in the winter 2010 – 2011. On all occasions the repair procedure has been replacement of the entire shore end to approximately 1000 meters from the beach. The systems 100% logical protection of all national services and automatic rerouting has secured effective contingency. Transatlantic carrier customers have unfortunately had inconvenience during the winter 2010 – 2011 since their traffic was interrupted during the cable damage. All damages has been repaired under the maintenance agreement with Alcatel Lucent Submarine Networks and the repair process has been exercised professionally as described in the service level agreement. Mobilization and spare part logistics was managed by the book and repair time could not be optimized given the long vessel transit time and arctic winter conditions. 3 different vessels were involved in the work with the opportunity for the Tele Greenland staff to learn the working routine and atmosphere on board the different vessels; Peter Faber, Fladbed vessel with mobile spread Mariner Sea, and IC Interceptor. Local vessel Mads Alex Viking has assisted all cable ships involved in the repair operations.

3 DECISION TO PROTECT GREENLAND CONNECT LANDFALL

In the beginning of 2011 it was evident that an unstable landing in Nuuk was unacceptable both due to expensive repairs but also to support carrier sales it was important to eliminate all weak spots in the cable system. The management team decided to pursue an efficient protection of the cable system. As a first step Tele Greenland ordered a report on the various options from the Canadian company C-Core. Report from C-core concluded that Glacial Ice in the fjord could have depths of 200 meters and consequently the landfall had to be protected to that depth corresponding to 1000 meters from the coastline. The report analysed an option of covering the cable with a thick layer of stones boxed in a steel grid box to prevent erosion of the material in the heavy tidal currents. Conclusion was that this solution is easy to implement, but do not give efficient protection. The ridge created on the seabed from this protective cover might even catch icebergs and make everything worse. Fencing of the water surface to guide icebergs away was also abandoned at an early stage due to the large mass of the icebergs combined with the rough weather conditions and large tidal differences at the site.

The only efficient solution at hand was Horizontal Directional drilling of both landfalls in two tunnels to keep physical separation and redundancy. Tele Greenland started a cooperation with consultancy company Sound and Sea Technology (SST) to scope and write tender document covering the work. Danish Geological Institute GEUS was contracted to deliver a desk survey of the geological features in the target area.

4 TENDER PHASE AND WET SURVEY

In the early spring of 2011 a tender was formed and submitted as a public bid according to Greenlandic legislation. 4 bids were received and one bid rejected at time of opening. 3 bids were feasible and roughly even, but the reservations in the bids placed Tele Greenland in an unpredictable situation and the budget could potentially exceed the pain threshold.

After rejection of the public tender an ice protection program was put in place where local vessel Mads Alex was set on standby to push dangerous ice away from the position of the cable landing. Video surveillance with night vision sight was put in place and these protective actions have worked in a sense that no ice damage has happened even though Greenland have had rough winters with massive glacial ice in the fjord.

It was clear that a bid with more narrow financial predictability called for a more detailed specification. A contract was made with Scottish company Caley Survey that at the time undertook advanced seismic surveys for the oil industry in the waters west of Greenland. Caley Survey had an equipped ship, Kommandor Stuart with very advanced seismic equipment. First and foremost the permit to undertake seismic surveys in these waters that are habitat for a wide range of maritime mammals had to be obtained. The authorities played this application very accommodating and the possibility to study the impact of seismic survey impact on maritime mammals was utilized, Tele Greenland hired a professional Maritime mammal observer and invited the authorities and biologists from The Greenland Nature and Environmental Institute on board the Kommandor Stuart during the entire survey.

SST Geologist planed the route and was Tele Greenland’s representative on board. The exit holes of the tunnels had to be decided on the fly since the environmental permit required photo documentation of the seabed before the drilling and also several samples of the seabed. Samples should be kept sealed and frozen and hence compared with samples after drilling to document no pollution due to spill of drilling mud.

Based on the seismic survey, Caley Survey submitted the geological report in October 2011 and the new and more precise scope and tender document was prepared by Tele Greenland and SST in December 2011. The major change in the scope compared to the public tender was, that same launch site would be used for both landfalls, to cut mobilization cost. In previous tender launch site was at the original cable positions. Moreover the geological information was of a much better quality, which is obvious as a wet survey with a scientific vessel is cumbersome compared to a desk survey. Since the response to the open tender was limited the legislation opened for an invited tender and material was send out to three contractors in the beginning of January 2012. A pre tender seminar was hosted by SST with an aim to cater for the tenderers' comments in the tender documents. All three invited contractors submitted thorough bids and SST scored all qualifications and prices in a comprehensive matrix. Negotiations were exercised during the winter and a letter of acceptance was granted 20th. of February to the Dutch company Visser & Smidt Hanab (VSH). VSH has extensive Horizontal directional Drilling experience, and a good track record.

The marine operation is contracted as a separate operation and the scope is to install the new landfall from the sea end through the bell mouth and conduit to be connected to the land cable at the vault. Hence the new landfall cable piece is connected to the old wet segment. The land cable is connected in the same planned outage slot to give minimal impact to the transatlantic carrier customers.

5 HORIZONTAL DIRECTIONAL DRILLING WORK

The construction site was mobilized through April and drilling commenced in the beginning of June.

Two tunnels at 12" diameter will be drilled from the launch site to a water depth of 209 metres. The tunnels will be +1100 meters long. The tunnel trajectory will follow a vertical position more than 7 meters beneath the seafloor. The exit is carefully planned to be at a suitable position where the otherwise steep sloping seafloor is relatively flat, at a plateau from the little ice age. This position secures that cable does not suffer any sharp downward bend at the exit.

A 5,25" steel pipe conduit will be installed from the beach man's hole vault to the tunnel exit. Conduits are heavy pipes with threads connections at each ends. The inner diameter of 4 inches gives a wall thickness of 22mm. Conduits must meet quality standards and have no shoulders or edges at the inner wall. The conduits will be pushed from land through the tunnel equipped with a so called "bull nose" at the far end. Bull nose is a rounded piece of conduit, with multiple nozzles at the end, to flush small obstacles away during installation. When conduit reaches the exit, the bull nose will be removed by a Remotely Operated Vehicle (ROV) and replaced with a so called "bell mouth". A bell mouth is a funnel shaped devise that is tailored to a 5,25" conduit and shall guide the cable into the conduit when installed from the sea end. The plan is to bore between 40 and 60 meters per day during a 12 hour working day.

Visser & Smidt Hanab (VSH) started the mobilization of the site in April 2012. A big HDD operation site takes up 50 by 50 meter space and the foundation as well as access road must be stable. The area sloping down towards the beach had the 4 meter of overburden soil removed and filled up with gravels. Two heavy 600 mm diameter by 16 meter long pipes was blasted down in the bedrock and adjusted to the exactly right starting azimuth and vertical angle to have a stable entering interface for the drilling aperture.

VSH erected the main elements; Diesel generator pack, 50 bar water pump, filter unit, drilling rig equipped with 5" drilling string terminated in a Gyro navigation unit and finally a 7 meter long mud motor with 12" drilling head. All machinery is operated in a control room staffed with drilling navigation engineer and a drilling control supervisor. The entire shift is staffed with 5 persons; Supervisor, Navigation engineer, Drilling control supervisor, Mechanical engineer, Mud control engineer.

The drilling work started 1 June 2012 and set off very successfully. The entering angle was changed late in the planning since VSH wanted to enter in a lower angle to reach solid rock as fast as possible and later change the vertical angle in a soft radius and eventually punch out in a 3 degree negative angle- We were very excited the first drilling days where the drill advanced more than 60 meters into the Greenlandic rock per day which was even better than the budget had planned for. After only two successful drilling days did the progress suffer a setback due to problems with the gyro navigation unit. Gyro unit is powered by 48Volt DC feed into the Gyro unit by a single 6mm square wire. The entire drilling string was tripped out and the Gyro retrofitted and drilling commenced again. After two more days Gyro failed again. The now even longer drilling string had to be tripped out again and Gyro and wire line had to be replaced once more. Problems with Gyro and wire line continued unfortunately throughout the project. VSH developed some solutions using more robust wire line and enforced the electrical joints between each section of line but reality was that we had to accept to drill several days blindfolded without navigation other than continue the direction the string had when navigation was lost. At tunnel one which is the most southbound one the drilling continued for four days without navigation to wear out a drill motor without tripping out again to undertake wire line repair work. After navigation was reestablished we learned that one does not drive blindfolded without being hurt somehow. Even though the experienced drillers tried to compensate for the known offset like a sailor hold his ship op against the wind drift, the drill have had a more negative vertical angle and the azimuth had drifted to the right. It was clear that we would never hit the planned exit position and had to accept that a new punch out position 20 meter deeper than planned had to be found by means of deskwork only. Fortunately the water in Greenland is deep and the slope towards the bottom continued long enough to host a deeper punch out position. One can regret the big cost to the survey company to find the ideal punch out spot which originally was a flat terrace from the little ice age. The most central learning for the next project is that a drill always naturally drifts downwards and to the right. One advice is to start a HDD drilling less steep and keep left.

As the drill string eats its way through the Greenlandic massive rock consisting mainly of hard dark Gneiss the drilling speed slowed down and the progress on a good day was 30 meters and often only 20. The tine schedule was revised several times and the budget equally increased as the contract scheme partly was time and material based.

Reaching 900 meters the scenario all involved had feared for; Mud pressure was lost in the drill string and no cuttings or drilling mud returned to the pool at the ground site. It appeared that fed mud was lost to the ocean or a huge cavity in the rock. Being more than 70 meters under the seabed and more than 150 meters to punch out we were surprised. VSH deployed the standard measure and flushed diamond seal through the drill string and into the leak. Diamond seal is a white chip compound consisting of hard crystals sized a bit bigger than rice. Deployed into water the diamond seal absorbs the water, expand and take form as hardened silicon. The good feature diamond seal has is that it can be deployed through the drill motor and drill head which means that it can be utilized without tripping the drill string out. It is a time consuming procedure to trip out from 900 meters.

After waiting one day for the diamond seal to harden and close the leak drill rig was started again still no returns of mud and chippings and we understood that the leak to the ocean still was open. Crew deployed diamond seal once more and obtained still no solution to the leaking problem.

New plan was to seal leak by grout consisting of 97% pure cement and 3% bentonite to make the grout mixture more flexible. The procedure to inject the grout into the leak was to install a so called packer at the end of the drill string. The packer is a rubber device like a car tire surrounding the drill string and by a external double hose system the crew can fill the packer with high pressurized water till it expand and make a perfect seal between drill string and tunnel wall. The packer and hose system was ordered from Holland.

The only way to make some useful progress while waiting for the packer was to start drilling tunnel 2 which is the north tunnel carrying cable to Canada. Tunnel 2 started up like tunnel 1 with good 60 meter progress the first days. Already at day 3 the mood was grave singe we suffered the first mud loss. Leak to the ocean was in the water, but only about 50 meters from the shore. A big cloud of betonite was making the crystal clear arctic water impossible to penetrate with the human eye.

Diamond seal was deployed as a routine and seemed to hold in the second attempt. Hereafter drilling continued like the experience in tunnel one and since we learned that the rock was harder than originally expected it was decided to reduce drill diameter from 12” to 9.5”.

Unfortunately the experience from tunnel 1 repeated when reaching 900 meters. Mud pressure was lost and we understood that a big crack was following the coastline 900 meters from shore since it reached good 200 meters from tunnel 1 to tunnel 2 and most likely extending even further. Diamond seal deployed as a standard two times with no result.

Tunnel 2 string was tripped back and a couple of days were used to undertake necessary rig maintenance waiting for the packer to arrive.

Packer system was rigged up and inserted in Tunnel 2. The grout compound was injected and crew waited 12 hours for hardening. Unpressured the packer and tripped back. Rigged the drill motor, drill head and gyro up again and started drilling – waiting without breathing the excitement was great seeing mudflow and chippings returning to ground level. Equally big was the disappointment when the pressure was lost again after drilling less than 10 meters. It was clear that there were multiple cracks down there and they were not necessarily interconnected. Procedure with diamond seal was still not working and crew rigged it all up to inject grout again.

After having injected grout in for the second time some returns was coming to the ground site and it was decided to continue and accept some 30% lost bentonite leaking into the environment. And we had punch out for tunnel 2 at 20th August. Conduit was installed without any problems a few days after. The crew did not even have to turn conduit during the insertion. The pipe slides down the tunnel towards the exit hole more or less by its own weight meeting no obstacles to flush or push away. The bullnose at the end of the conduit was only tightened by hand enabling the ROV hence to dismount it by applying as little force as necessary. The bullnose is a one meter long piece of pipe closed in the far end and rigged with nozzles to inject high pressured water for flushing obstacles away.

Conduit was left in position with a safe over length to be finally adjusted during a later planned ROV operation.

Going back to tunnel one at the end of august and run the packer and grout operation once more. Grout did not seal the leak completely and we experienced the well-known result that some flow returned but still 30% loss. After some days the crew ran out of bentonite. Having round 150 meters to punch out it was decided to drill with water as a driving force for the drill motor. Using water instead of bentonite have more wear and tear on the drill motor and even more serious water does not have the bentonite feature that it can flush cuttings the long way back to the ground site. We had to accept the risk that drill pipe could get stuck in the tunnel and not could be taken out. A lost drill pipe and bit have the consequence that entire tunnel is lost and work has to start over. Just with less than 100 meters to punch out a new shipment of bentonite arrived to Greenland and the crew managed to retrieve all piled up chippings by turning the pipe and flushing with max flow. Bentonite have fantastic features to fill small cracks and by changing the viscosity of the fluid it can carry heavy clippings to an elevation above 200 meters from where chippings were cut.

Successful punch out were met 20 September and crew as well as Tele Greenland management were relieved. Two day spend on conduit installation with no problems.

The specialists for ROV inspection had arrived to the site and the ROV was deployed and the exit was located with some problems at the ROV organized by VSH had very limited navigation features. Basically ROV could only move and see having no idea of position or heading.

It was clear that both conduits had huge over length and the now randomly chosen exit points were far from ideal. Only action taken was to adjust the over length to 5 meters beyond the seabed for both exits by pulling conduits back with the drill rig.

VSH did a good job by securing the conduits at the ground site by welding them to the 600mm pipe with two prepared shells fitting the components.

As a final action for VSH the crew flushed an endless piece of mule tape down to the end of the bullnose. Purpose of mule tape is to have a messenger wire that the ROV can catch and bring to the surface when that operation shall be exercised. Mule tape is a ¾"wide flat rope with a breaking force of 2,8 tonnes.

A few days after VSH had demobilized the entire site and chartered a boat to take all gear out of Greenland to the next job.

6 MARINE OPERATION

The scope of the marine operation is to dismount the bullnose by means of a ROV. Mount a bellmouth at the end of the conduit. Pull a prepared Single Armored cable through the conduit and finally splice new cable landing to existing segments on the sea bed and on land.

Alcatel Lucent Submarine Networks ASN was contracted to deliver cable ship to undertake the operation under Tele Greenland management. ASN took no responsibility for the success since this operation never had been undertaken before at this depth. The contract was under the regime of the maintenance agreement and daily rates set up front. However lots of special costs appeared during the detailed planning and all in all were the budget revised in many loops. The insurance company called for a special ice management program – recommended by IMO, but not mandatory in these waters. Lots of special tools one may require, but never came into play. Lots of specialists and representatives involved made the budget hard to manage.

The ship available, Ile d'Àix, arrived after a tough transit in the north Atlantic winter alongside Nuuk Harbor 10th November. Ship loaded provisions and spare cable in Nuuk and was ready to commence the operation at 12th November as planned. The Ice management regime had set a time window ending 1st .December and after that deadline ship had to leave do to ice risk.

12th November a lot of measurements was taken to prepare the work and ROV was launched just to experience some problems with hydraulics and some time was spend to do repair work at a very cold deck. Finally the ROV seems to be operational and launched for a second time. One exit was located and the crew noted that conditions were not good as we knew already from first inspection. Pipe was exiting 4 meters above the floor coming out of a wall with a big boulder at one side. Consequently the ROV had to swim during the operation which is not easy in the high tide current.

The very experienced ROV operator tried to fit the tool to unscrew the bullnose multiple times and eventually he concluded that the tool did not fit. ROV docked at the ship again and a measurement of the tool revealed the classical error that tool is produced to the exact measure and not with some positive tolerance. A new tool was designed on board by good craftsmen and the Bullnose unscrewed by the ROV successfully. Hence the ROV mounted the bell mouth at the end of the conduit. The bell mouth acts as a fairlead for the pulling and will make a perfect dock for the bend restrictor.

Beach team flushed the mule tape out by help from the local Fire Brigade to the ocean and the ROV caught it and brought it to the ship. The ship crew attached a 12mm messenger wire to the mule tape and the beach team pulled mule tape and 12 mm messenger wire successfully to the shore.

On shore the Beach Team had erected a big 30 tones winch equipped with 2400 meter 24 mm torsion free wire.

Ship pulled messenger wire and 24mm pulling wire back to the ship and connected the prepared mini block to the end of the pulling cable. A mini block consists of the SAL cable and a piece of double armored cable that will fit the existing segment coming to the splicing operation.

The beach team started to pull the sal cable through the conduit and the transition between wire and cable slides smoothly into the bell mouth. Coming to the length where the SAL sable finally installed will meet the end of the conduit the ship crew mounted a prepared bend restrictor to the SAL cable. The bend restrictor is 7 meter long and 25 cm in diameter, made of massive nylon with slots to absorb force at the critical exit point.

The bend restrictor went into the water like a big fish and met the bell mouth in an ideal angle and the ROV did not have to intervene in anyway but did only observe. The pulling force was never near the max force of the winch – actually never more than one tonne.

At the beach team the crew had designed a brilliant tightening device to keep the cable tight with a force of 1 tonne to keep the bend restrictor safe in place. 20 meter of over length is coiled up into the heavy concrete vault.

Having completed the pulling operation the beach team and ship crew prepared splicing to existing segments which are standard operations well known in the business.

South landing was handled with the same procedure and commenced 17.November.

7 EVALUATION AND LEARNINGS

Money spends at survey and geologist did not bring a lot of value since exit position ended up in random positions. Cracks and features of the rock were not discovered up front.

It is a good idea to prepare a good launch site with stable surface.

Consider how big tunnels you really have to drill. Advisors recommended 12” but 9.5 Inches was sufficient when the rock appeared to be extremely hard.

You cannot make more progress than max 30 meters per day in hard rock. When you reach a crack you will lose time and it will be expensive. A HDD drill always drifts down and to the right. Do not underestimate failures on Gyro navigation systems. Be sure you have enough bentonite supply to cover a mud loss.

It is an advantage to charter a right sized ship. Il D`Aix was very big for the job. It is also preferable to undertake marine operation during summer time. You really do not need a 30 tonne winch to pull the landfall through the conduit. Make sure the equipment is tested and operational when you start.