SHALLOW WATER CABLE ABRASION
MANAGING THE RISK

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Abstract: Until fairly recently, cable abrasion has mostly been associated with faults in deep water where cables have been installed across, or near to, seabed features. The classic solution available to combat this threat is to increase the level of cable protection by utilising Lightweight Protected (LWP) instead of Lightweight (LW) cable. This additional protection can be planned for because the seabed features are visible from the marine route survey data.

However, today, we are increasingly seeing abrasion related cable faults in shallow water where maximum protection (Double Armour – DA) has already been specified. Unlike the deep water faults, some of the environmental factors that lead to abrasion in shallow water are not obvious and are not measured as part of the marine route survey. Furthermore, as the world's ocean floor becomes ever more crowded with submarine cables, routing away from areas where adverse factors exist is becoming much harder to achieve.

The goal of this paper is to raise the awareness within the Submarine Cable Community of shallow water cable abrasion, its causes and steps that can be taken to mitigate the risk.

1. WHY AND WHERE DOES ABRASION OCCUR?

Cable abrasion occurs when the cable is moved across a hard substrate such as a rocky sea floor. This movement is usually in the form of an oscillation and it is this forwards and backwards motion that leads to the cable rubbing across the sea floor and abrading. In some cases where the sea floor substrate is comprised of soft rock, the cable also abrades the sea floor, smoothing the rock and leaving cable sized grooves. The substrate does not even have to be particularly hard for this phenomenon to be produced. There are examples of abrasion where the cable is moving across relatively 'soft' sediments such as sand, with the sea floor acting as 'sandpaper' on the cable.

The main cause of cable movement is water flow across the cable. This flow could be the result of seabed currents, estuarial outflow, tidal flows, wave action and swells generated in the deep ocean or by storm events. With the exception of seabed currents, the impact of these flows will mostly be limited to landfall areas of submarine cable systems. Wave action will typically impact cables in less than 10m water depth but storm events and deep sea originating swells have been seen to affect cables down to 30m water depth. Seabed currents could occur anywhere and may be associated with a geographical feature such as straits or narrows.

2. WHAT IS THE IMPACT OF ABRASION?

Cable abrasion over time will inevitably lead to a fault. If no specific action is taken to prevent recurrence of a fault due to abrasion, then there will be multiple faults over time at the same location. On a repeatered system, the fault will initially manifest itself as a shunt fault and ultimately, fibre failure, loss of traffic and a cable break.

The mechanism of failure starts with the removal of the polypropylene serving around the armour wires exposing the galvanised steel wires to the abrasive seabed and the protective bitumen layer to the 'washing' effects of the flowing water. Further cable movement then starts to remove the galvanising from the armour wires leaving exposed unprotected steel. The salt water then corrodes the steel which in turn, rusts through and breaks.

This process is then repeated for the inner layer of armour (if present) ultimately exposing the polyethylene insulated lightweight cable to the effects of abrasion. The insulation is compromised finally leading to contact between the conductor and sea water and thus a shunt fault occurs.

As can be seen from the above, abrasion is the primary cause of the fault but corrosion takes a leading role by accelerating the process considerably.

Figure 1: Example of Abraded Cable

It is possible, using well established stability calculations (DNV-RP-F109), to establish what level of water flow wi1l cause cable movement. For a typical armoured submarine cable, flows as low as 1 knot perpendicular to the cable can induce cable movement, not a particularly high figure in the marine environment. However, the effect of the angle of the flow to the cable is significant. The more oblique the angle of the flow, the less movement of the cable is induced.

3. WHAT IS THE SOLUTION?

The primary solution is evidently not to route cables in areas where:

- Burial is not possible
- There are strong seabed currents
- Landfall sites are subject to high energy wave action/swells or storm events

Of course this is part of the holy grail of submarine cable routing. In reality, it may not be possible to do this due to any number of reasons associated with permits, wayleaves, environmental requirements, national boundaries or simply congestion.

Figure 2: Cable Congestion at the Southern End of the Red Sea

Wherever possible, at landfalls for example, consideration should be given to improving the routing approach such that the angle of the cable to the direction of the flow or swell is far more oblique which could make a significant positive difference to the stability of the cable. However, it should be recognised that this may not always be possible due to other external constraints.

The real difficulty in routing cables away from areas of potential risk from damage due to abrasion is the clear identification of the precise location of such areas. An abundance of oceanographic data exists from the many buoys deployed throughout the world's oceans. However, these provide mainly data on surface conditions and do not provide information relative to the cable position on or close to the seabed. Certainly, websites for the surfing community can be a useful source of data for wave action at landfall sites as is collecting information from other local marine/maritime sources. Since it is clear that these sources are all somewhat limited in their usefulness for the identification of precise locations where cable could be at risk from abrasion, it is important to explore methodologies which can be used in order to better assess the existence of potentially damaging flows on or close to the seabed.

4. IDENTIFICATION OF AREAS OF RISK

The first place to begin this process is the Cable Route Study (CRS or DTS). The standard requirements for a CRS (see ICPC recommendation number 9) include 'an examination of all existing data to identify surface, mid-water and bottom currents'. The difficulty here is with the term 'existing data' relating to bottom currents as there is very limited data in the public domain and what exists tends to understate the magnitude. There are a number of academic or scientific organisations around the world that conduct various oceanographic studies, but these can be difficult and time consuming to locate and access. In our view, a different approach is needed at the CRS stage which goes beyond 'an examination of existing data'. This approach entails specific climatic modelling.

There are many MetOcean organisations that provide weather forecasting for the Maritime industry. Several of these have access to complex climate modelling systems which can forecast both surface and seabed currents. Threshold parameters can be set to allow the production of risk maps of a chosen area. As an example, the modelling can show areas where seabed currents of more than 1 knot exist as well as areas where surface currents of more than 4 knots exist (see figure 3 below).

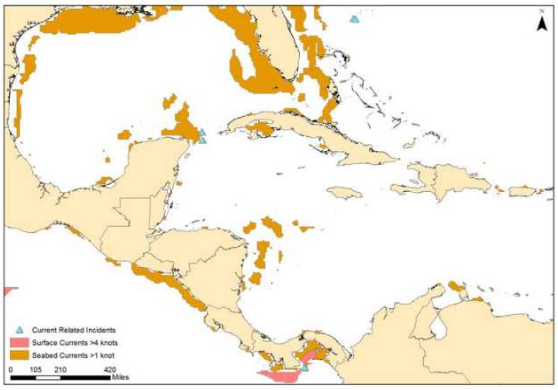

Figure 3: Example of a Risk Map

These risk maps can be overlaid onto the GIS platforms used for route engineering and can provide an early warning at the planning stage of the project of potential risk areas. This initial identification can then enable more detailed specific climatic studies to be undertaken in order to better define the seabed flows in terms of magnitude and direction (see example in figure 4 below).

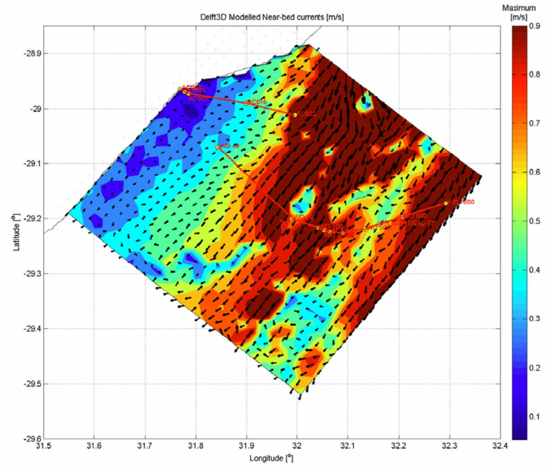

Figure 4: Direction and Magnitude of Maximum Near-Seabed Currents

This information can then be used to assist the route engineering process in order to optimise the cable route in terms of positioning and angle towards the direction of flow.

Such modelling also has the advantage that it takes into account variability over time as it is usually based on the previous 10 years of climatic data unlike physical measurement which is only valid for a point in time but modelling is a prediction and not a measurement. The most common way to measure seabed currents is to deploy current meters in areas where a risk has been identified. However this is a relatively costly exercise and may take up to one year to implement if seasonality is a factor. Such timescales are not considered practical in the context of the typical implementation of a submarine cable project.

There are more efficient ways to collect data that could be explored. Most shallow water surveys make use of towed sensors at a distance of about three times water depth from the survey vessel and 10-15m above the seabed. The location of the sensor is tracked using acoustic positioning therefore, by noting how far off line the vessel is, will provide an estimation of the magnitude of any current and as the survey is conducted along the line, this offset will be the resultant of the speed and direction relative to the route, albeit a snapshot in time.

Some shallow water surveys also call for a burial assessment survey (BAS) conducted by means of cone penetrometer testing (CPTs). The CPT rig is placed on the sea floor along the route at discrete locations (usually every 4km) and it is relatively simple to fit a current meter to the CPT frame. This will provide useful measurements albeit at discrete intervals and at a point in time but may highlight a potential risk.

5. RISK MITIGATION ACTIONS

On the basis that it is not possible to route the cable away from areas of risk due to other constraints, then there are a number of actions that can be considered in order to mitigate the risks from abrasion and improve system reliability.

At land falls and in shallow water, a number of solutions exist. The most common of these is to encase the cable in cast iron pipes (Articulated Pipe) which is applied to the cable by attaching two half shells. This is normally attached by divers so is usually limited to diver operational depth (20-30m) but for deeper water depths it can be deployed on the cable as it is laid from the stern of the cable ship. This does have a depth limitation, which is typically around 50m.

Articulated pipe is made from a ductile version of cast iron and has excellent performance in abrasive environments and has good impact resistance against rocks being thrown around in high energy surf. The addition of articulated pipe greatly increases the stability of the cable by adding considerable weight (16kg per meter) and more stability can be provided by clamping the pipe to the rock where possible.

Figure 5: Clamping Articulated Pipe

Clamping the cable is also an alternative to articulated pipe. It provides stability and prevents cable movement but does not provide the additional benefits of impact resistance and protection against being snagged by small boat anchors.

Application of articulated pipe over a large area is generally uneconomic as the application process can take time and can be necessarily very weather dependent. An alternative to be considered is to shallow bury the cable with a rock trencher. Rock trenching is generally slow and therefore expensive but economies can be realised by only trenching to a depth sufficient to stabilise the cable, no more than 30cm. This will greatly improve the productivity of the rock trenching machine and reduce cost. This approach was recently adopted off the north west coast of Australia where the cable is under threat of damage from powerful storms (Cyclones).

Figure 6: Typical Rock Trencher

For areas of risk in deeper waters beyond the reach of articulated pipe, there are a number of potential solutions to stabilise the cable and limit movement where significant seabed currents exist. It is common practice in the Oil & Gas industry to stabilise pipelines and umbilicals either by rock dumping or by installing concrete mattresses over the product. However neither is a cost effective method for a submarine telecommunications cable except for very short lengths. In particular, rock dumping requires a specific type of vessel which may not be readily available at the required location resulting in high mobilisation costs. On the contrary, concrete mattresses can be installed from the cable ship or possibly the post lay burial vessel removing the need for high mobilisation costs but as each mattress is typically only 6m long, installation is a slow, and therefore costly, process for any significant length.

A more cost effective solution is to install a cable product which is inherently more stable in the presence of seabed currents. This means a product with greatly increased weight but only a small increase in diameter (higher density) as stability increases with weight but reduces with an increase in diameter. A typical double armour cable has a weight in water of 3kg per meter with a diameter of 40mm whereas a heavy double armour variant weighs 6kg per meter with an increase in diameter of only 10mm. The main benefit of this approach is that, unlike applying an external means of stabilisation (such as articulated pipe, rock dumping or mattressing), there is no impact on the cost of installation.
A further improvement to the product is to apply an outer polyethylene sheathing. Although the polyethylene is not as resistant to abrasion as steel, it has the added benefit of preventing the polypropylene roving (yarns) from

unravelling once it has been cut by abrasion (as a result of cable movement across hard ground). This stops the armour wires being exposed to the washing effect of the current which, over time, will remove the bitumen coating and ultimately the galvanising.

Figure 7: Sheathed Heavy Double Armour

6. CONCLUSIONS

Shallow water abrasion faults occur as a result of seabed water flow. Routing cables away from such flows is the first line of defence but first you have to identify the areas at risk. If it is not possible to do this because of other constraints (congestion, conflict with other sea bed users, maritime boundaries), this paper presents a number of mitigation measures that can be adopted to reduce the risk of faults.