Understanding the Effects of Shallow Soils on Sub-seabed Cables using a 3D Acoustic Profiler

Introduction

High voltage sub-seabed cables are becoming more common within seas around the world in the form of electrical interconnectors, offshore wind farm export and inter array cables. Ensuring that sub-seabed cables are installed at the minimum depth of lowering requirement and continue to be in subsequent years, is essential to cable integrity.

For an offshore wind farm development, the typical cost of cable supply and installation is in the order of 8-12% of overall capital expenditure (CAPEX) cost. However, is it understood that 80% of insurance claims for European offshore wind farms are cable related and typically occur during the construction phase (Carbon Trust, 2015). The minimum depth of lowering for a cable needs to be taken into consideration, as too shallow may result in the cable being exposed at the seabed, leading to possible damage while too deep may risk damage to the cable due to overheating (Dresser, 2021).

This study focuses on the survey of the Viking Link interconnector cable between the UK and Denmark in the southern North Sea. Whilst an interconnector cable may not be directly linked to an offshore wind farm (OWF), the results of this study can be applied to OWF export and inter array cables. The Sub-Bottom Imager™ (SBI) 3D acoustic profiler was used in conjunction with a Teledyne TSS 350 cable tracking system, which was operated by Ocean Infinity. This presented an opportunity to carry out a comparison between the two systems in their ability to detect and provide depth measurements of the interconnector cable.

SBI Data Acquisition

The SBI consists of three chirp sources and a 40-channel receiver array, which is arranged in the across-track direction (Figure 1). The source and receivers are mounted on a fixed frame along with an Inertial Navigation System (INS) and Doppler Velocity Log (DVL). For this survey, the SBI was mounted to a remotely operated vehicle (ROV).

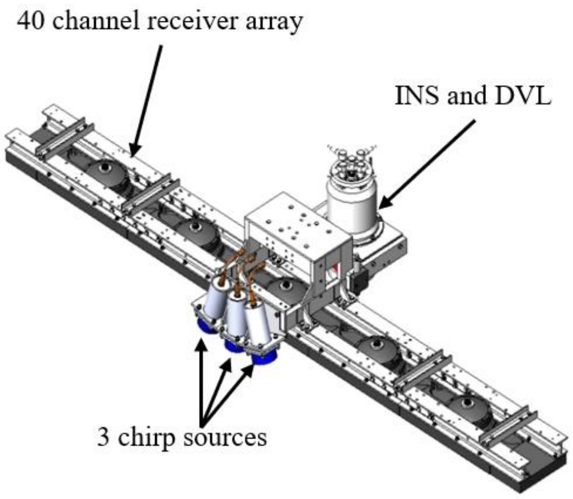

Figure 1 *3D image of the SBI system and its primary data acquisition components*

As the chirp signal propagates from one of the chirp sources and comes into contact with a cable, the signal is diffracted and these diffractions are captured by the 40-channel receiver array (Figure 2). This enables the cable to be positioned within the 3D acoustic volume, which can then be interpreted to produce top of product (ToP) or depth of cover (DoC) measurements if both the cable and seabed reflection are interpreted. Typically, the ToP interpretation is combined with a bathymetric dataset to calculate the cable depth of lowering (DoL), which takes the measurement from the ToP to the mean undisturbed seabed.

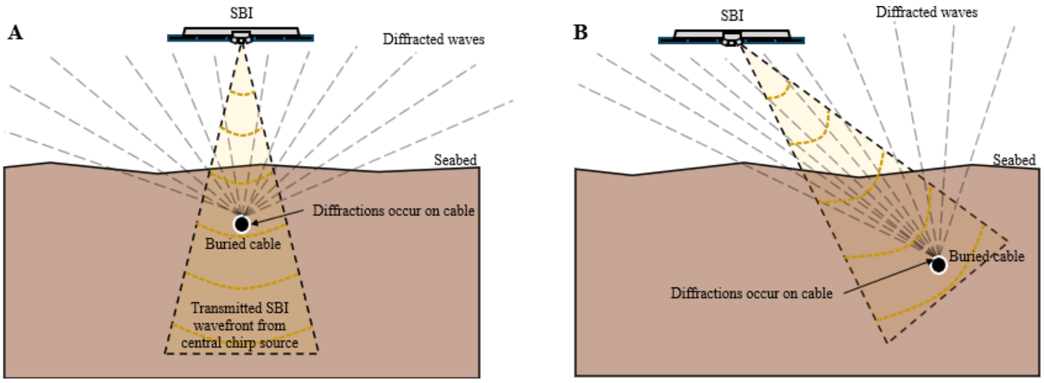

Figure 2 *Images showing the SBI travelling in the along-track direction with the SBI chirp signal propagating from a chirp source. Image A shows the central chirp source signal propagating directly downwards and the resultant diffraction from the buried cable. Image B shows the port chirp source signal propagating to the port side of the SBI.*

Using a combination of synthetic aperture sonar (SAS) and beamforming, the high resolution content of the SBI data is recorded and rendered into a 10 cm³ binning grid, which enables cables with a diameter of 8 cm to be detected, however cable diameters as small as 5 cm have been detected in certain shallow soil settings. The SBI has a 60° aperture in the along-track direction, which enables the system to image a cable 100 times or more in the SBI swath (Dinn, 2012).

Shallow Soils within the Viking Link Interconnector Cable Corridor

The sediments along the Viking Link interconnector cable corridor are primarily sand based, with an increase in gravel content present in the nearshore sections and an increase in clay and silt content where the water depth is at its maximum along the central part of the route. Bedforms such sandwaves, sand ridges and sandbanks are present in the nearshore sections. The TSS 350 was the primary cable detection and tracking sensor used for the survey, with the SBI being used where necessary.

Comparison Between the As-built and As-found Cable Tracking Data

The time between the installation of the Viking Link Interconnector cable and the cable as-found survey was a minimum of approximately 3 months. There is a general reported increase in the depth of lowering of between 0.5 to 0.75 m, which is expected as the cable has gradually settled into the shallow soils. However, the TSS 350 as-found data reported oscillations in the cable that were not present in the as-built data, which presented some questions on the results (Figure 3). Cable trackers that use electromagnetics to detect and track cables, such as the TSS 350, record a signal, which represents the cable. Apart from looking at the data acquisition parameters, there was no other way to interrogate the data, therefore these cable oscillations could be considered by some to be an artefact of data acquisition.

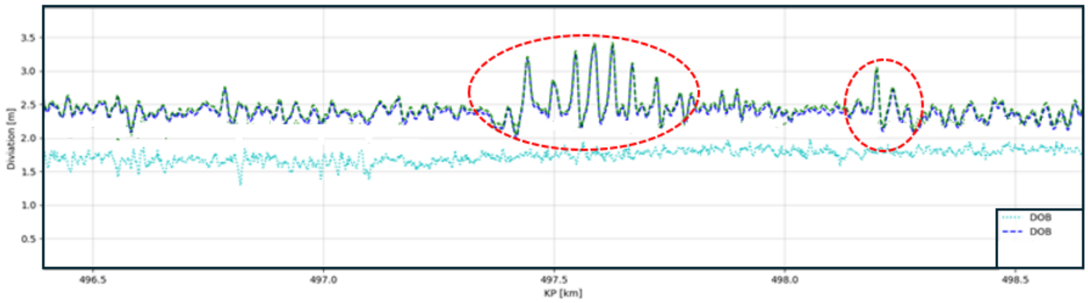

Figure 3 *Graph showing the cable depth of lowering (termed DOB in example) comparison between as-built (light blue – as-built data) and as-found (dark blue – TSS 350 data) cable surveys. The red circles indicate the cable oscillations that were present in the as-found data, which weren't reported in the as-built survey. It should be noted that the Y axis shows an increase in depth in an upwards direction.*

Comparison Between the TSS 350 ToP data and the SBI ToP interpretation

A 10 km comparison line was acquired to compare the TSS 350 ToP data and the SBI ToP interpretation (Figure 4). The comparison was not directly over the example graph presented in Figure 3, however similar cable oscillations were observed. The results of the comparison showed that the ToP from both systems had good alignment in both absolute depth and general cable trend. With the support of the SBI data, there was an increase in confidence that these cable oscillation features were real, especially as one of the systems uses electromagnetics (TSS 350) and the other uses acoustics (SBI) to detect the cable.

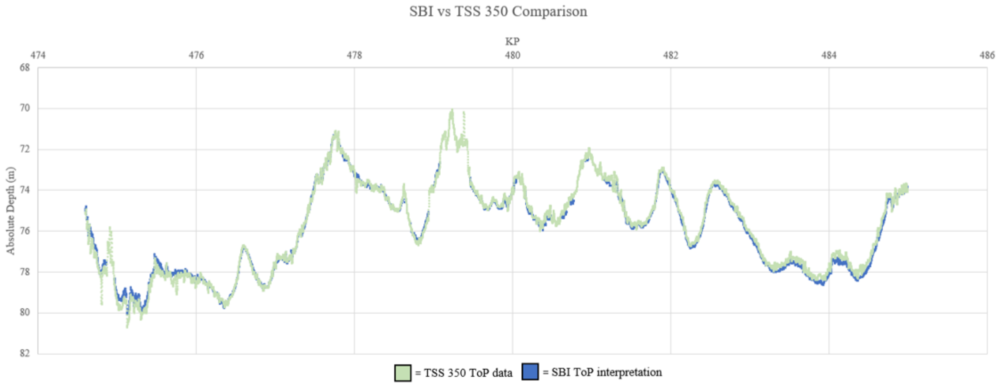

Figure 4 *Graph showing the 10 km comparison between the TSS 350 ToP data (green) and the SBI ToP interpretation (blue).*

Understanding the interaction between the cable and shallow soils

Unlike an electromagnetic system, a 3D acoustic volume not only provides the position of the cable but also valuable information on how the cable is interacting with the shallow soils. The shallow soils information obtained may provide indications why a cable has a varying burial depth and/or whether there is a problematic shallow soil unit. From Kraken Robotics experience, shallow soils, which show limited to no significant acoustic impedance contrasts (described as homogenous), tend to show cables with continuous burial depths. On the contrary, where shallow soils show various acoustic impedance contrasts (described as heterogenous), the cables depths tend to undulate and, in some circumstances, shallow significantly (Figure 5). Gravels and cobbles present in shallow soils during trenching operations may cause the cable to be shallower than expected due to coarse sediments falling out suspension immediately, lining the base of the trench and shallowing the cable (Wilbert et al, 2022).

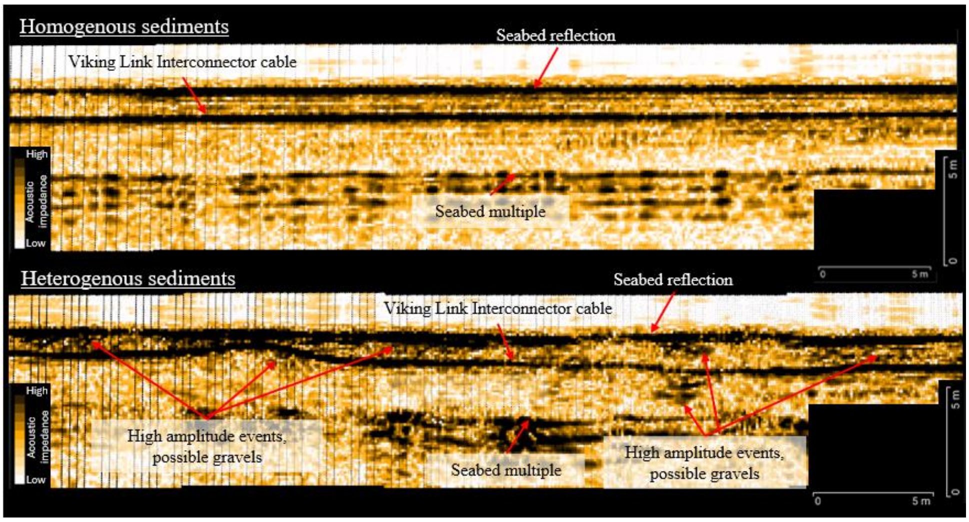

Figure 5 *SBI data examples showing the burial characteristics of the cable settling into homogenous sediments (top image) and heterogenous sediments (bottom image).*

In another SBI cable survey, due to possible changes in the shallow soil composition resulting in cable trenching difficulties, a cable is observed to be in freespan (Figure 6). Where the trench is at its shallowest, there are clear changes in the acoustic impedance contrast in the underlying shallow soils.

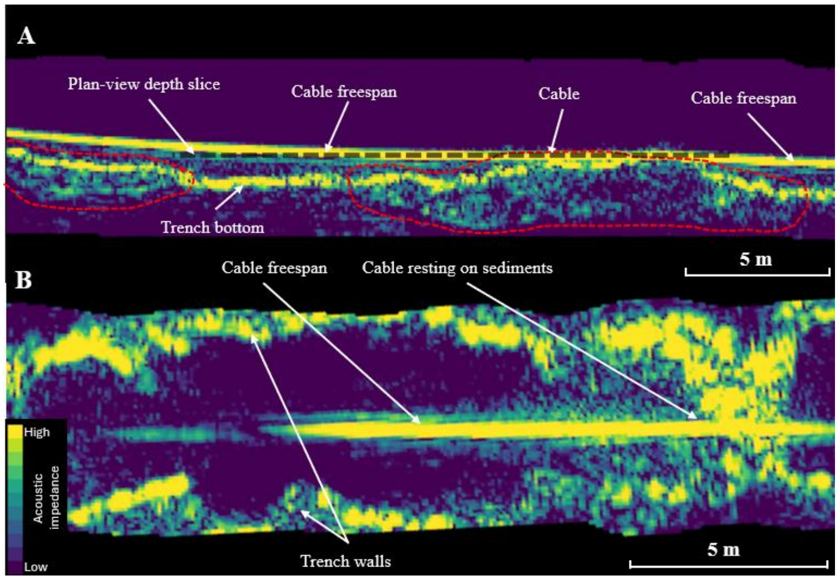

Figure 6 *SBI data examples showing a cable freespan and a trench encountering challenging shallow soil conditions. The top image (A) is a profile view of the cable and the bottom image (B) is in plan-view. The red polygons highlight varying acoustic impedance contrasts, which may be causing the trenching difficulties. The grey dashed line in image A indicates the location of the depth slice profile in image B.*

Conclusions

A 3D acoustic volume is an effective method of tracking a cable for burial purposes, similar to systems that use magnetics. However, the 3D acoustic data is able to provide information on how the cable is interacting with the shallow soils, which may provide useful information on how to approach challenging shallow soils when it comes to trenching design. While cable route geophysical and geotechnical surveys provide a significant amount of information on the shallow soils conditions, 3D acoustic profiler data can be used to provide further information on challenging, heterogenous soils.

Acknowledgements

I would like to thank National Grid, Energinet and Ocean Infinity for allowing this data to be presented and Michael Noel, Senior Geoscientist at Kraken Robotics for the data analysis completed on this project.

References

Carbon Trust [2015] Cable Burial Risk Assessment Methodology: Guidance for the Preparation of Cable Burial Depth of Lowering Specification, CTC835.

Dinn, G. [2012] Field experience with a new sub-bottom investigation tool: Acoustic 3-D imaging of the sub-seabed, *2012 Oceans*, 1-9.

Dresser, B. [2021] Offshore Wind Submarine Cabling Overview, Fisheries Technical Working Group. Tetra Tech, Inc. NYSERDA Report 21-14.

Wilbert, V., van Weerdenburg, R., Scheel, F. and Hoeskstra, R. [2022] Empire Wind 2 Sediment Transport Study. Modelling of trenching-induced sediment dispersion during the installation of the EW 2 export cables. Deltares. Document No.: 11207423-002-HYE-0003.