Defining the Buried Boulder Risk for an Offshore Wind Farm with 3D Acoustic Imaging

Introduction

Successful subsea cable installation comes down to proper planning and adequate installation methods based on the geological conditions of the installation route. Understanding the most suitable installation technique for different geological conditions is common practice across the industry (Jaign 2021 and Department for Business Enterprise & Regulatory Reform, 2008). The challenge is to accurately define the geological conditions along the entire installation route as misinterpretation can result in project delays, inadequate installation techniques, damaged products, and/or loss of profit.

Kraken Robotics Sub-Bottom Imager^{TM} (SBI) and Acoustic Corer (AC) technology has the capability to image sub-surface features by producing three dimensional (3D) volumetric models. Using these sensors, Kraken Robotics were able to assess the shallow soil conditions of both the export and inter array (IAC) cable corridors and a select number of wind turbine generator (WTGs) locations for the Baltyk II and Baltyk III Offshore Wind Farms (OWF), located within the Polish waters of the Baltic Sea. This involved surveying approximately 455 km of proposed cable routes to approximately 5.5 m below seafloor using the SBI. The AC was used to provide 3D volumes at 27 WTG locations to a maximum imaging depth below seafloor of 26 m, providing a total of approximately 108 km^3 of data for all 27 locations.

Approximately 15,300 sub-surface discrete anomalies, interpreted to be buried boulders were resolved, along with numerous dense accumulations of discrete anomalies interpreted to be clusters of buried boulders. This interpretation allowed for proper planning and design of adequate installation methods to reduce cost, time and risk.

The Technology used During the Survey

Both the SBI and AC generate 3D acoustic volumes through the use of synthetic aperture technology where acoustic impedance contrasts are imaged using the back scattered energy from discrete anomalies and lithological changes in the sub-surface.

The SBI signal transmission is conducted by three chirp projectors with the beam pattern aligned with the horizontal direction of the swath. The SBI can be mounted on a remotely operated vehicle (ROV) or the SeaKite ROTV platforms. The reflected and diffracted signals are detected with a 40-channel receiver array, which are aligned in the across-track direction. The projectors and receivers are continually moved forward with the projectors emitting an acoustic sweeping pulse in rapid succession at 45 Hz which translates into a 3D volume of data visualising the seafloor and shallow soils (Figure 1).

The AC is deployed onto the seabed and consists of two rotating booms. Each boom has both transmitting and receiving packages and they rotate 180^{o} during a scan, creating the 360^{o}, 14 m diameter acoustic core that can reach a maximum of 60 m below the seafloor (depending on the shallow soil conditions) (Abbott et al, 2023). The acoustic packages contain both a high frequency and low frequency sweeping chirp, along with a Parametric (Innomar) source and each sensor produces an individual acoustic core data volume.

Interpretation Process

For the SBI acquired data along the cable routes, the interpretation was broken up into discrete anomalies and dense accumulations of discrete anomalies (Figure 2). Each discrete anomaly was evaluated and given an individual score for shape, size, relative acoustic amplitude and repeatability to assign it with a confidence score of high, moderate or low based on the combined score. This confidence rank was implemented to provide a probability of the discrete anomaly representing a buried boulder.

Dense accumulations of discrete anomalies were defined by their level of discrete anomaly concentration and lateral separation between discrete anomalies. The density classification was used to provide an indication of the potential difficulties that would be encountered during the installation stages of the subsea cables.

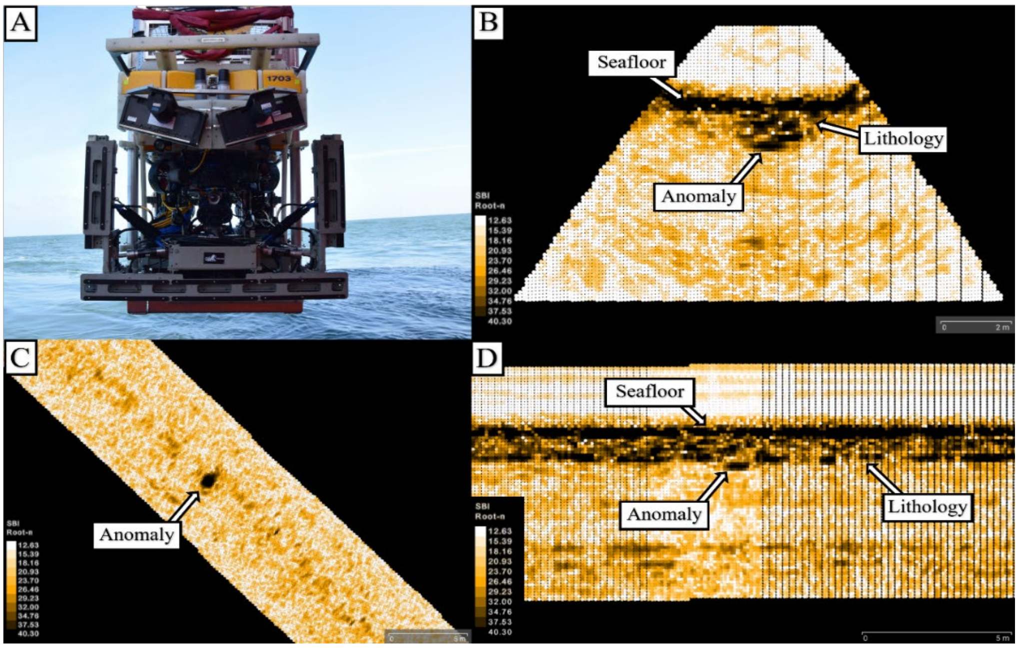

Figure 1 *A) The SBI system mounted on a ROV. Images B to D show SBI volumetric data highlighting an imaged discrete anomaly below a lithological layer in B) Cross-track view, C) Plan view, and D) Along-track view.*

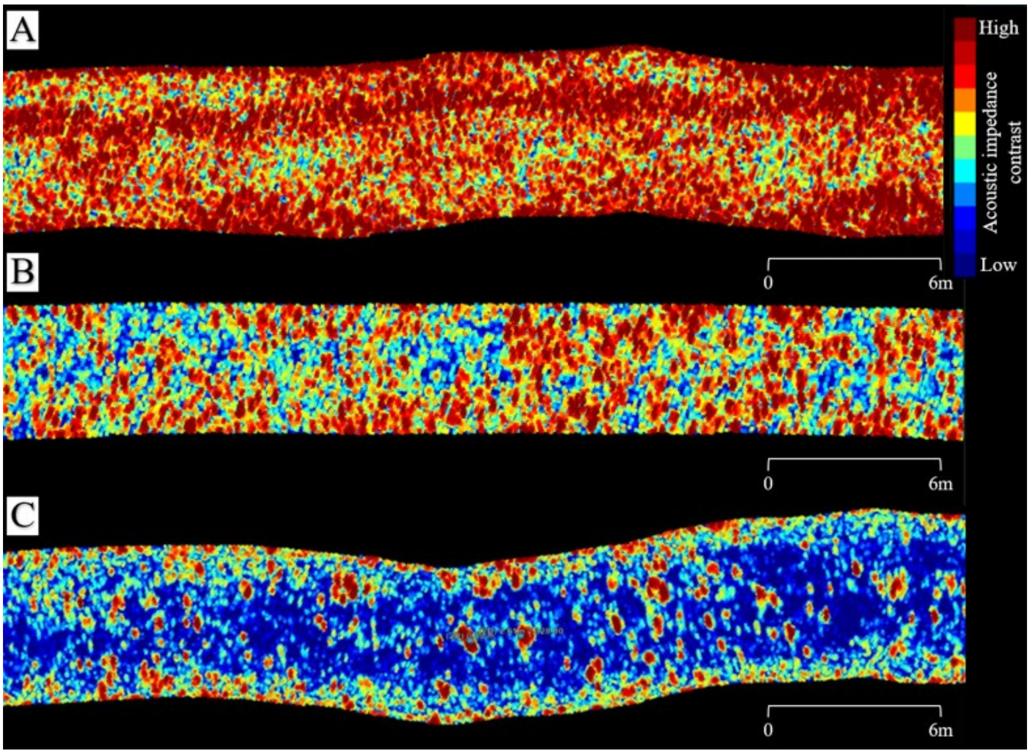

Figure 2 *SBI plan view data examples showing different classifications of dense accumulations of discrete anomalies. A) Unsorted gravels, cobbles, and boulders where there is no clear separation between discrete anomalies. B) Very dense area of discrete anomalies interpreted to be buried boulders laterally separated less than 1 m. C) Dense area of discrete anomalies interpreted to be buried boulders laterally separated between 1 - 5 m.*

Results

Approximately 15,300 discrete anomalies interpreted to be buried boulders were resolved along the cable corridors and at the WTG locations; the majority of which were located between 0.3 and 0.6 m below the seafloor (Figure 3). Along with the interpreted discrete anomalies, there were 419 areas of dense accumulations of discrete anomalies interpreted to be buried boulders, with varying area sizes. Focusing the discrete anomalies to an assumed cable depth of lowering target of 2.0 m (Department for Business Enterprise & Regulatory Reform, 2008), it is observed that 12,218 discrete anomalies, interpreted to be buried boulders had the potential of influencing the subsea cable installation.

With the SBI and AC surveys and interpretation being performed independent of each other, their reported discrete anomalies at the WTG locations were integrated to ensure that the same discrete anomalies were reported.

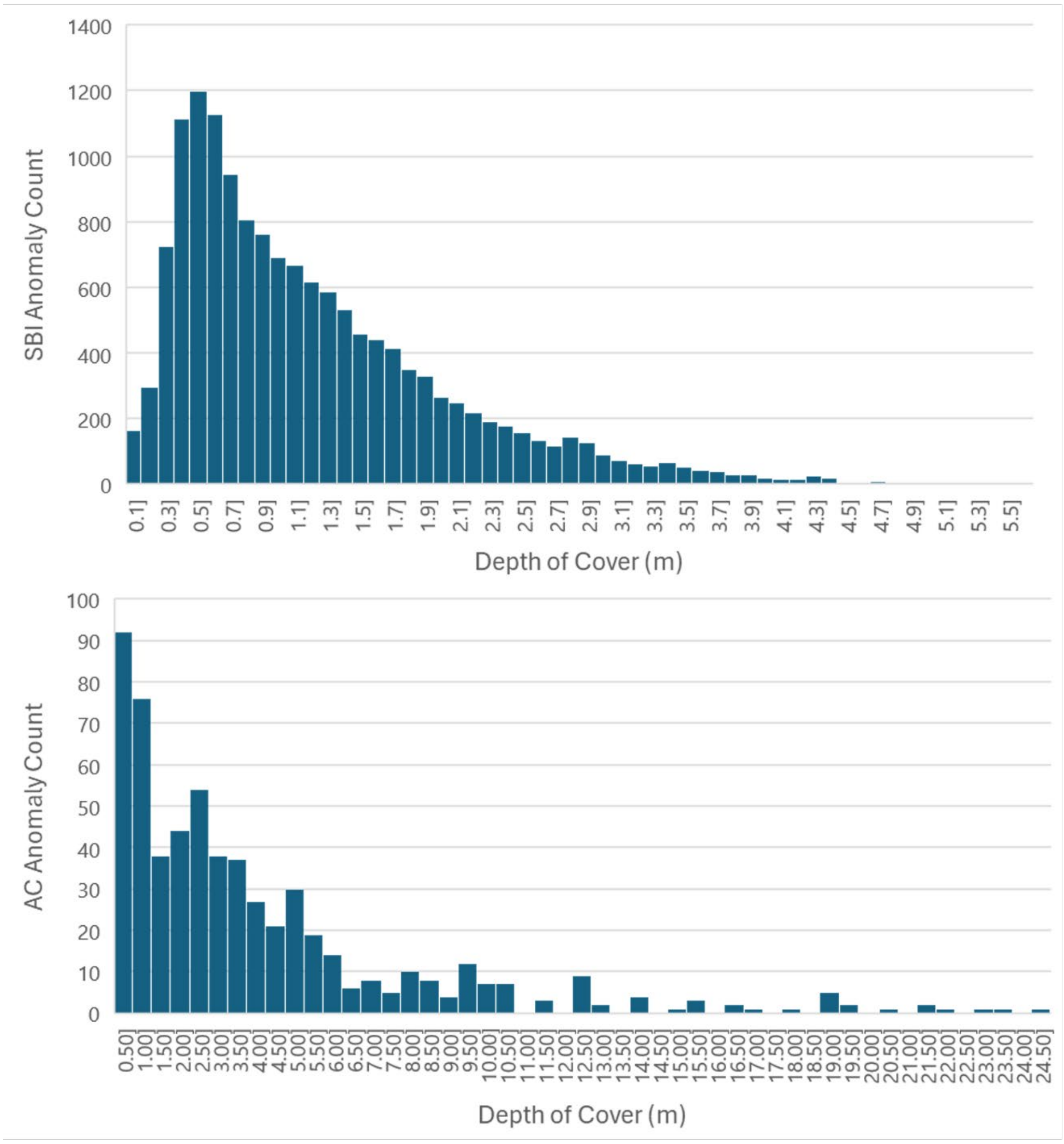

Figure 3 *The total discrete anomalies resolved by both the SBI (top) and AC (bottom), broken up into imaged depth below seafloor ranges. The deepest imaged discrete anomalies were 5.6 m and 24.3 m below seafloor for the SBI and AC, respectively.*

SBI to AC Interpretation Comparison

Where the SBI and AC data overlapped at the proposed WTG locations, this allowed a comparison between the interpretation. The locations of the reported AC discrete anomalies that were covered by the SBI data swath were analysed to assess whether they were resolved in the SBI data and how they compared with regards to length and width measurements (Table 1). It was found that the SBI resolved 96% of the AC reported discrete anomalies, where the highest correlations of 100% was at the seafloor and at the bottom of the SBI data swath (5 – 6 m below seafloor). The imaged size of each correlating discrete anomaly was analysed and it was observed that the SBI data were imaging discrete anomalies with an average -0.02 m and +0.01 m difference in the length and width, respectively with an uncertainty of +0.2 m for the overall length and width measurements.

Table 1 *The number of reported discrete anomalies reported by the AC at different depth compared to the number of corresponding discrete anomalies imaged within the SBI data.*

	Depth below seafloor							
	0 m	**0m–1m**	**1m–2m**	**2m–3m**	**3m–4m**	**4m–5m**	**5m-6m**	**Total**
AC	29	85	52	60	30	10	5	271
SBI	29	83	50	59	26	9	5	261
Correlation	100%	98%	96%	98%	87%	90%	100%	96%

Conclusions

Combining the SBI and AC technology to image the planned offshore wind farm site for buried boulders provided vital information on the shallow soil conditions. The interpretation provides additional information to ground models on top of the geophysical and geotechnical data previously acquired. This in turn would be used to allow the planning and design of adequate installation methods to reduce cost, time and risk.

References

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