Offshore wind power enhanced by ultra-high resolution technology

Ultra-high resolution 3D seismic imaging has the potential to revolutionize offshore wind power development by providing detailed insights into subsurface conditions. This cutting-edge technology enhances turbine foundation design, reduces risks, and optimizes project costs, supporting the rapid growth of the offshore wind industry and its role in renewable energy.

As the global shift towards renewable energy accelerates, offshore wind power has become a vital component of the world's energy landscape. Driven by ambitious government targets, the offshore wind sector is experiencing rapid and unprecedented growth. However, as the number and scale of projects rise, developers are confronted with substantial challenges in maintaining the structural integrity and longevity of wind turbines and their foundations. The solution to these challenges lies beneath the ocean's surface, within the complex subsurface environment where turbines are anchored or piled.

Enter 3D Ultra-High Resolution Seismic (UHR3D) technology, a powerful tool that can transform our approach to understanding and preparing the seabed for offshore wind infrastructure. This advanced geophysical method offers developers unparalleled insights into the subsurface, facilitating more informed decision making, minimizing risks, and streamlining project timelines.

The need for advanced subsurface imaging in offshore wind

Offshore wind farm development requires a thorough understanding of the subsurface, known as a ground model. This is crucial for several reasons. First, it ensures the structural integrity of turbine foundations, allowing them to withstand the harsh marine environment for decades.

It also helps mitigate risks by identifying potential hazards such as shallow gas pockets or buried boulders, which could complicate foundation installation. Lastly, a comprehensive ground model can improve costs by enabling more efficient foundation designs and installation processes, potentially lowering overall project expenses.

Traditional methods of subsurface characterization, such as 2D seismic surveys and extensive geotechnical sampling, have served the industry well in its early stages. However, as wind farms grow larger and move into more challenging offshore environments, these methods are showing their limitations. 2D surveys often provide incomplete subsurface images and lack the resolution needed for modern offshore projects. Moreover, relying solely on geotechnical sampling can be time consuming and costly, especially when covering large areas.

The UHR3D advantage

UHR3D surveys benefit offshore wind developers in several ways. They provide enhanced resolution and coverage, offering continuous, high-resolution data across the entire survey area. This allows for the detection of small-scale features, such as boulders or shallow gas pockets, that might be missed by 2D surveys.

The continuous 3D dataset also improves accuracy, enabling a more precise interpretation of soil units, which results in a more reliable ground model essential for foundation design and installation planning.

While the initial investment in UHR3D may be higher than traditional methods, it can prove more cost-effective in the long run. The comprehensive data reduces the need for additional surveys and can streamline geotechnical investigations, saving both time and money. Developers can make faster and more confident decisions about turbine placement and foundation design due to the complete and accurate subsurface image.

Additionally, by providing a detailed view of potential subsurface hazards, UHR3D helps mitigate risks during the construction phase, potentially avoiding costly delays.

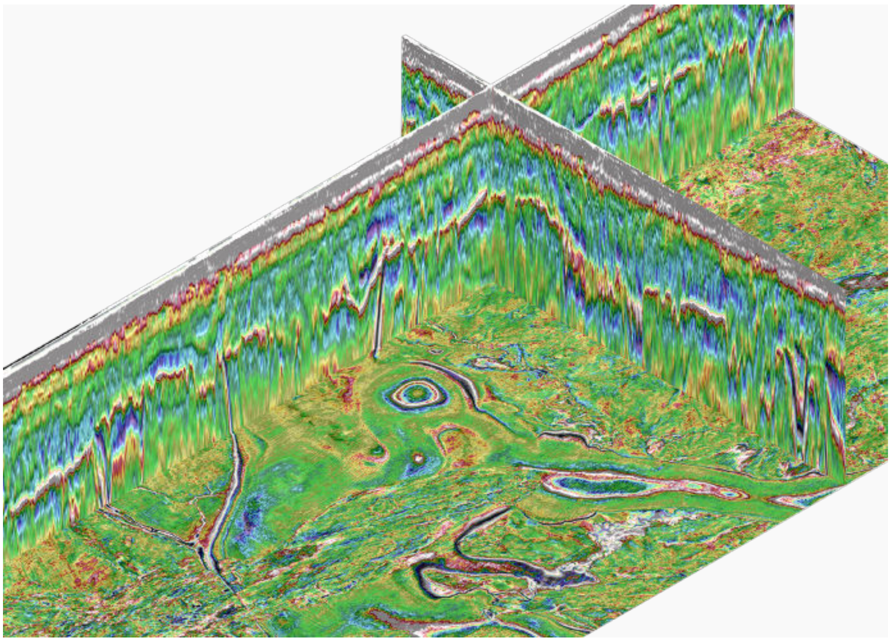
From survey design to quantitative interpretation

Let's look at the key stages of a UHR3D survey and how they contribute to offshore wind farm development.

Survey design and acquisition

The goal of survey design is to optimize acquisition parameters to meet geophysical and geological objectives while minimizing survey time. For offshore wind projects, this typically means achieving a horizontal bin size of 1 to 2 meters and a vertical resolution of 2 to 3 kHz.

Recent advancements in survey design have dramatically improved the efficiency of UHR3D acquisition. By using wide-towed multi-sources and a large number of streamers, modern surveys can cover vast areas in a fraction of the time required by older set-ups.



At the Ten Noorden van de Waddeneilanden (TNW) Wind Farm Zone, predicted cone resistance values showed a strong correlation with measured CPT data, even in geologically complex areas. This level of detail and accuracy in soil property prediction was previously unattainable with traditional methods

The acquisition setup typically involves several components. Multiple streamers, often eight or more, are towed behind the vessel. In addition, multiple sparker sources are towed in a wide configuration. The depths of both the streamers and sources are carefully controlled to boost data quality. Simultaneously, additional geophysical measurements, such as multi-beam echo sounders and sub-bottom profilers, are collected to provide comprehensive data.

This configuration allows for the collection of near-zero offset data, which is crucial for achieving the desired resolution in shallow water environments where most offshore wind farms are located.

3D seismic imaging, especially with UHR3D, can help lessen the environmental impact on marine ecosystems during the construction and operation of offshore wind farms. This technology allows for the simultaneous gathering of other geophysical measurements, which means fewer surveys are needed, and each survey has the potential to disturb the marine environment. Plus, having better data can reduce the need for geotechnical sampling, which also helps protect the environment.

Data processing: turning raw data into actionable insights

Processing UHR3D data involves several steps to enhance data quality and maximize the value of the survey. Key processing stages include deghosting, which removes unwanted reflections caused by the sea surface to improve data clarity. Advanced techniques, including machine learning, are used to address challenges posed by varying sea states and high-frequency data.

Designature is another important step, shaping each source signature into a common broadband zero-phase wavelet, which enhances resolution and ensures consistency across the dataset. Sea surface statics correction compensates for variations in sea surface height, ensuring seismic events align properly throughout the data.

Demultiple involves the use of advanced algorithms to remove unwanted multiple reflections that can obscure primary seismic events, thus improving the overall clarity of the subsurface image.

The final stage, imaging, utilizes 3D Kirchhoff Pre-Stack Time Migration (KPSTM) to accurately position and focus the seismic wavefield. This step is crucial for creating a high-resolution 3D volume, which can then be used for detailed interpretation.

The result of this processing workflow is a high-resolution 3D seismic volume that provides unprecedented insights into the subsurface structure and properties.

Quantitative interpretation: from seismic data to soil properties

One of the most exciting applications of UHR3D data in offshore wind development is quantitative interpretation (QI) for soil property prediction. This approach combines seismic data with geotechnical measurements to create a comprehensive model of subsurface properties across the entire survey area.

The QI workflow typically involves several key steps. First, acoustic impedance is derived from seismic reflectivity and velocity data.

This impedance is then correlated with cone penetration test (CPT) measurements for key soil units. Using these correlations, soil properties such as cone resistance can be predicted across the survey area.

This data-driven approach offers several advantages for offshore wind developers. It provides detailed variations in soil properties at the resolution of the UHR3D data volume, offering a more accurate understanding of site conditions. Added to which, it reduces the need for extensive CPT campaigns, potentially lowering project costs. This approach also enables better planning and optimization of turbine foundation designs, allowing them to be tailored to specific site conditions.

UHR3D offers some great cost-saving opportunities, particularly by cutting down on the number of geotechnical sampling campaigns needed. Since UHR3D data gives a continuous view of the entire area, it allows for more efficient planning of CPT. This 3D volume can help identify sub-areas that require less CPT sampling, ultimately saving time and resources.

Future directions: pushing the boundaries of UHR3D technology

As the offshore wind industry continues to grow and evolve, so will the capabilities of UHR3D technology. Several exciting developments are on the horizon.

Enhanced acquisition technologies will likely involve the use of longer offsets, additional source types such as air guns for lower frequency data, and the integration of autonomous vessels to improve efficiency and coverage. Machine learning and AI are also set to play a major role, with automated processing workflows powered by machine learning algorithms promising to significantly reduce project turnaround times while improving the consistency of results.

In addition, advanced inversion techniques, including elastic inversion and full-waveform inversion (FWI), will lead to more accurate predictions of subsurface properties, further reducing the need for extensive geotechnical sampling. Finally, greater integration with other geophysical methods, such as controlled-source electromagnetics (CSEM) and marine magnetics, will offer a more comprehensive understanding of the subsurface, enhancing the quality of offshore wind farm development projects.

One challenge in the widespread adoption of UHR3D technology, especially in regions where offshore wind energy is still developing, is the supply/demand imbalance. There may not be enough supply to meet the short- to medium-term demand. However, if the demand remains strong, contractors like TGS can respond by ramping up their supply to meet market needs.

Advancements in subsurface imaging technologies like UHR3D could significantly shape the future of renewable energy production globally, particularly in emerging offshore wind markets. One key goal is to shorten the time it takes for new wind farms to connect to the grid and start supplying electricity to consumers. With UHR3D, this timeline could potentially be reduced by half, accelerating the transition to cleaner energy and enhancing the overall efficiency of offshore wind projects.

UHR3D as a cornerstone of offshore wind development

With the offshore wind industry striving to achieve ambitious renewable energy goals, the importance of UHR3D technology in facilitating efficient and sustainable development is undeniable. As wind farms expand in size and venture into more challenging environments, the insights gained from UHR3D will be crucial in overcoming technical obstacles and reducing the cost of clean energy production.

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