Measuring Offshore Wind Resources

How Scanning Lidar Improves Resource Assessment at Sea

By Evan Osler

To select the right offshore wind site, estimate the future energy output of a wind farm, and determine the best layout for the turbines, project developers must conduct wind resource assessment (WRA) campaigns on site. This is a critical phase of the successful development of wind farms.

WRA campaigns on terrestrial sites have traditionally been performed using meteorological towers equipped with wind and weather sensors, which record data for at least one year to help characterize long-term wind conditions. In the realm of offshore wind energy development, however, conventional met towers are both prohibitively expensive to install and extremely time consuming to permit. Furthermore, as fixed point measurements, they present both a challenge in spatial representativeness (since a single met tower typically cannot represent the potential wind resource variability in a large offshore project site) and in long-term value (since a met tower located in the middle of a future turbine array becomes far less useful as a meteorological reference once the wind farm is built, thanks to wakes from adjacent wind turbines disrupting the wind resource to be measured).

In recent years, floating lidar buoys that profile vertically have gained significant traction as low-cost and quick-to-deploy alternatives to conventional offshore met towers. At typically 10 percent of the cost of an offshore met tower, lidar buoys are quite often now the preferred choice for finance-grade wind data collection in offshore environments. Meanwhile, many offshore wind developers choose to couple both technologies—met tower and floating lidar—and take advantage of the unique benefits of each.

Alongside the increased deployment and industry acceptance of floating lidar profilers, project developers have taken a fresh look at side scanning long-range lidar systems for WRA. Using the same measurement principle as vertically oriented shorter-range lidars, these systems are designed to measure wind characteristics remotely from a distant fixed location that is typically horizontal to the project area. The location could be onshore from the coastline or offshore from an existing multipurpose platform.

Scanning lidars were historically designed for aviation industry uses, primarily in the realms of wind shear and wake vortex detection, and are therefore already well proven for operational use in mission-critical applications. The relatively simple process of deploying a scanning lidar on a coastline or on an existing structure makes it economical and logistically practical compared to both offshore met towers and floating lidar vertical profilers. As with the advent of floating lidars for WRA a few years prior, many savvy wind developers now take advantage of this additional technology as a supplement for the onsite, hub-height wind measurements that are imperative for third-party financing.

WINDCUBE Scanning Lidar

WINDCUBE 100S/200S/400S is a product line of scanning lidar systems designed and manufactured by LEOSPHERE SAS and sold and serviced by Renewable NRG Systems in North America. WINDCUBE scanning lidars are used commercially for offshore WRA during wind energy project development, as well as wind farm operations (wind turbine power performance testing, short-term forecasting and turbine wake assessments). Future additional uses include advanced, wind farm-scale turbine control for power output optimization and load mitigation.

Advances to the WINDCUBE scanning lidar platform in the past 24 months have included improved measurement range and repeatability, reduced physical size, increased system reliability, and significant development and validation of related algorithms to make the most of the collected "raw" lidar measurements.

WINDCUBE scanning lidars measure the radial wind speed at ranges up to 10 km over a series of azimuth angles. The principle of the measurement is that each of the beam angles measures a different projection of the same horizontal wind speed. The raw measurements are then post-processed into time series data sets of horizontal wind speed and direction, at either discrete "virtual met tower" locations or across an entire 2D plane. Sequential, repeating horizontal scan sweeps (plan position indicator, or PPI scans) at different vertical angles allow for multiple heights of measurement and a reduction, or even elimination, of horizontal and vertical wind uncertainties—both important drivers in overall energy estimation uncertainty and financing.

Performance Verification by DNV GL

Two WINDCUBE 400S scanning lidars were field-tested and validated by the well-known independent engineering firm DNV GL against a high-quality met tower at the Janneby test site in Germany in 2015. Ten-min. average values of post-processed horizontal wind speed and direction were compared between the lidars and the met tower located 1.8 km away. The results from the test show that the WINDCUBE scanning lidar meets the high standards set by the wind energy community, with correlation of nearly 0.98 along the prevailing wind direction and mean wind speed error of less than 0.3 m/s. Mean direction error compared to industry-standard wind vanes averaged less than 2°.

The scanning lidars operated with a range resolution of 200 m, using a beam elevation angle of 3°, and targeting the top-mounted anemometers of the mast at 100 m above ground. For this verification approach, DNV GL and LEOSPHERE defined key performance indicators (KPI) and related acceptance criteria (AC) in order to allow a maturity assessment of scanning lidar for wind data quality and reliability in terms of system and data availability. This maturity test was focused on the potential capacity of scanning lidars to be used for supporting and complementing onshore and offshore WRA-related measurement campaigns.

The total system availability achieved by the lidars across the entire 60-day campaign was 100 percent. Data coverage for reconstructed 10-min. wind data from the treated PPI sector scans was well above 85 percent. The wind data from both scanning lidars showed a resemblance to the reference wind measures, indicating a consistent behavior among the two individual units.

Based on these results, DNV GL concluded that the WINDCUBE scanning lidars under test are considered suitable to successfully support and complement WRA-related measurements in a qualitative manner in benign terrain conditions, e.g., scanning offshore from the coast for larger area wind speed and direction measurements.

DNV GL's performance verification followed important earlier work on WINDCUBE scanning lidars by Danish Technical University (DTU) aimed at determining optimal PPI sector widths, scanner speed, pointing accuracy and repeatability, and validation of conversion algorithms.

From Independent Validation To Commercial Application

Following third-party validation at Janneby, the two WINDCUBE 400S lidars were deployed as part of wind resource assessment campaigns at two French offshore wind sites, located respectively in Tréport in Upper Normandy, and the Isles of Yeu and Noirmoutier in Vendée. The objective of the campaigns is to make the best use of the wind resource available at both locations to reduce the costs associated with offshore wind development.

The barrier to collecting hub-height wind data in many offshore wind areas has never been lower, whether for preliminary site prospecting purposes or late-stage, finance-grade energy assessment. Scanning lidar measurement campaigns are, in general, most defensible with either prior validation (as in the case of DNV GL's tests at Janneby), on-site validation against an existing met tower or vertical lidar located within the project area, or a mix of the two approaches. Optimal data quality and recovery are typically achieved when the projected lidar beam is roughly parallel to the prevailing wind direction, as opposed to being orthogonal to it. What this means in practice is that the best place to locate a scanning lidar for a project area with, for example, a prevailing westerly wind is to the east or west of the area, not to the north or south of it.

For offshore wind developers looking at new wind energy areas within a 10-km range of coastline or existing platforms, it should be clear that scanning lidar is now both an acceptable and economical method for WRA. Proper measurement campaign design in conjunction with an experienced independent consultancy can yield improved project economics and lower capital costs compared to offshore WRA campaigns of the past. ST

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