Wind Resource Measurement by Laser Anemometry

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Remote sensing methods such as sodar and laser anemometry (lidar) offer a means of obtaining accurate wind profiles for wind resource assessment, and hence reduce costs and risks associated with the siting of fixed masts. However, these techniques need to be extensively validated in order to obtain widespread acceptance by the industry. At the forefront of this process, QinetiQ, a UK research and development laboratory, has developed ZephIR – a laser anemometer which exploits decades of lidar research. QinetiQ began a programme to develop a commercial fibre-based lidar in 2001 in close collaboration with Risø, Denmark's National Research Centre; its ZephIR product is now becoming an established tool for wind profiling in the wind energy industry. In March 2007 Natural Power exclusively licensed the technology from QinetiQ to bring ZephIR to the global market and commence serial production. ZephIR has been tried and tested by the community, including an offshore evaluation programme with Germanischer Lloyd's WindTest on the FINO1 platform, and has demonstrated 100% availability and exceptional correlations with fixed masts. Systems have been deployed successfully around the world in many demanding applications that illustrate the flexibility and robustness of the solution.

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Wind Resource Measurement by Laser Anemometry

Harnessing a Tried and Tested Novel Technology

Introduction

Laser anemometry was first developed in the 1970s using gas lasers, and until recently has been used primarily as a research tool. However, systems based on solid-state sources and off-the-shelf telecommunications equipment, and operating at a wavelength ( ) of 1.55µm, are now available, offering the capability of routine autonomous remote wind speed measurement.

ZephIR, aptly named after 'Zephyr', the Greek god of the west wind (replacing 'yr' with IR - Infra Red), quantifies wind quality in terms of speed, direction, turbulence, shear and flow angle. The product can be rapidly deployed, configured and redeployed, with both on-board data storage and wireless data transmission. There is no requirement for site permitting, it removes any risk of working at height, and it provides wind farm developers and turbine manufacturers with all-weather operation.

Figure 1. ZephIR installed in New Zealand

Figure 2. QinetiQ engineer Adrian Coffey (26 July 1968 – 30 August 2006), who worked on ZephIR

In addition to this ground-breaking technology the system has the benefit of being specifically designed to suit the needs of the wind industry. As a result it is robust, easily configurable, redeployable for micro-siting and, most importantly, has proven its suitability in all environments from a Canadian winter to an Australian summer. ZephIR's twin-skinned glass reinforced plastic (GRP) structure ensures it can perform no matter whether it is deployed in arctic conditions at -25°C or desert conditions at +40°C.

ZephIR timeline

March 2003: Turbine-mounted system (Nordex), for proof-of-principle

January 2004: Ground-based prototype wind profiler delivered to Risø

September 2004: Development of ZephIR product begins

March 2006: Offshore deployment on FINO1 platform with Germanischer Lloyd's WindTest

March 2007: Natural Power acquires exclusive licence for ZephIR

A significant advance towards acceptance of lidar techniques has been made with the inclusion of research involving the ZephIR lidar within the remote sensing work package of the FP6 Integrated Project 'Integrated Wind Turbine Design' (UpWind). The project aims to assess the performance of the lidar under a wide range of atmospheric conditions in both simple and complex terrain, with an overall objective of achieving formal certification for lidar methods.

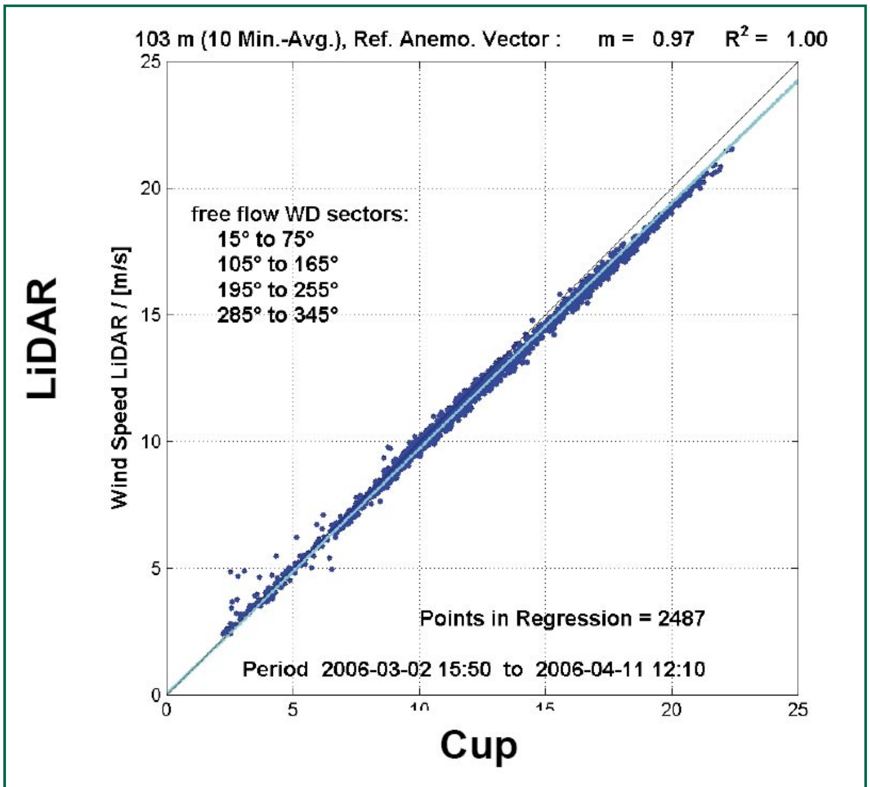

Figure 3. The results of the evaluation programme

Market Needs

Until now, the wind industry has generally studied wind patterns and turbine performance using traditional fixed masts. This raises issues such as the need for site permitting, working at height, and increased uncertainty in the reliability of data due to complex sites and inadequate mast heights.

The new remote sensing techniques offer the real potential to reduce the risk of uncertainty in datasets as a complement to the existing methodologies. They also offer flexibility and deployment scenarios that have been unrealistic until now.

Modelling techniques have always played a key part in the industry's understanding of wind flow behaviour and prediction. The true value of using these in conjunction with the validations available from remote sensing techniques is now being understood.

Principles of Operation

The principle by which lidar measures velocity was described in an earlier article: 'Wind speed at light speed: laser radar', D.A. Smith, WindTech International, November 2004. An infrared beam of coherent radiation illuminates natural aerosols (particles of dust, pollen, droplets etc.) in the atmosphere, and a small fraction of the light is backscattered into a receiver. Motion of the target particles along the beam direction leads to a change in the light's frequency through the Doppler shift effect. This frequency shift is accurately measured by mixing the return signal with a portion of the original beam, and sensing the resulting beats at the different frequency on a photodetector.

Since a single lidar measurement only provides the component of wind speed along the beam direction, it is necessary for the direction of the beam to be altered in a scanning pattern in order to generate a measurement of the wind speed vector. A conical or VAD (velocity-azimuth-display) scan pattern is commonly used; as the beam moves, it intercepts the wind at different angles, thereby building up a series of measurements around a disc of air from which the wind speed vector can be derived. ZephIR obtains each line-of-sight measurement in 20 milliseconds, and 3 seconds of data (giving approximately 150 such measurements) are used to derive the horizontal and vertical wind speed components and wind direction. The system can interrogate five chosen heights up to 150m in sequence by focusing the transmitted beam.

Lidar is silent and unobtrusive, and can operate successfully even when part of its scan is obscured. This confers great flexibility so that the system can be located adjacent to masts or buildings or in forests. Stationary objects within the beam pose no major problem, other than the loss of wind measurements from the relevant obscured sector of the scan. Turbulence data relevant to the wind industry may also be extracted from lidar signals; this is an area that is benefiting from further research and verification through field comparisons.

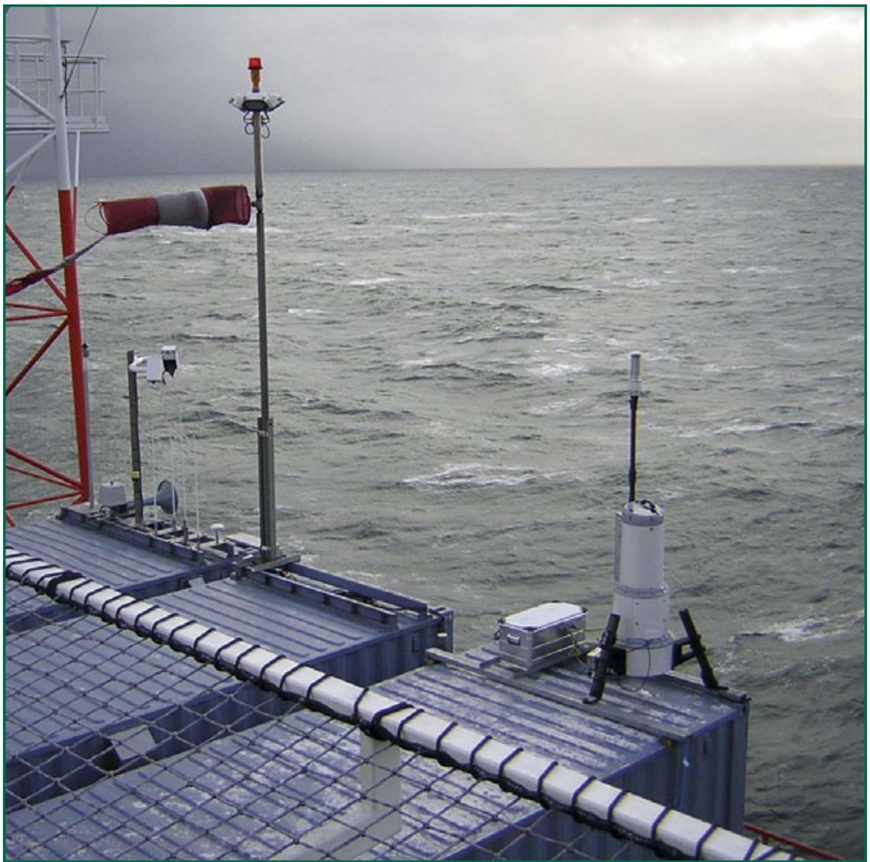

Figure 4. ZephIR installed on FINO1 offshore platform

Results

Thorough validation of any remote sensing method is a necessary step before its routine acceptance in the wind energy industry. Currently, the clearest demonstration of validity must be provided by direct side-by-side comparisons between a lidar system and a fully instrumented 'met-mast'. Rigorous comparisons must be carried out with great care to avoid a number of phenomena associated with cup anemometers. These are well known and include the following:

- shadowing of the cup anemometer by the mast from certain directions;
- cup sensitivity to any vertical wind component;
- * topographic effects leading to non-uniform flow across the area occupied by the mast and lidar scan (including turbine wakes);
- valid cup anemometer calibration.

The evaluation programme on FINO1 was reported at the recent EWEC 2007 conference in session DT2. ZephIR's availability while on FINO1 was reported as being 100%, with no weather dependence reported. The correlations calculated were as shown in Figure 3.

Work was also performed as part of the same programme onshore in Brunsbüttel against a 125m test tower and turbulence comparisons demonstrated an impressive correlation. The programme was deemed a success and ZephIR is now installed on the Beatrice wind farm, a flagship project for offshore wind energy development in Scotland, the UK and Europe, and is the primary source of wind measurement for the REPower 5M machines installed there.

The many comparisons performed so far with ZephIR are providing mounting confidence in the validity of the lidar technique. Notably, this has been achieved in a short timescale, with the first such comparison being completed as recently as the summer of 2004. There is currently a need for agreement on a unified method to allow meaningful comparison between the performance of different remote sensing systems.

Biography of the Authors

Ian Locker is a Chartered Electronic Engineer with a Masters Degree in Business Administration. He has worked in the wind industry for seven years and during that time has been responsible for QinetiQ's renewable energy business and has recently joined Natural Power to lead their ZephIR manufacturing, sales and service provision business. Michael Harris is a physicist and was educated at Oxford and Newcastle universities. He has conducted fundamental optics research at JILA (Boulder, Colorado) and the University of Essex, and is currently Technical Team Leader for Remote Sensing at QinetiQ Malvern.

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