UpWind

SIXTH FRAMEWORK PROGRAMME

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Remote Sensing

THE CHALLENGE

Measuring wind speeds for the evaluation of modern large wind turbines requires measuring masts comparable in height to the wind turbines. These instrumented masts are very expensive. The challenge of this work package (WP) is to research into remote sensing methods as a more cost effective alternative to measuring masts. Two such alternatives are SODAR (an acoustical version of RADAR) and LIDAR (an optical version of RADAR). The SODAR receives reflections of an emitted sound pulse from atmospheric fluctuations of temperature and speed and measures the mean wind speed based on the principle of the Doppler shift. The LIDAR receives reflections of an emitted laser beam from atmospheric particles and measures the wind speed also based on the Doppler shift. Recently new LIDAR technologies have emerged which are targeted towards wind measurements over height ranges relevant to wind turbine applications, and which do not require the expense and logistics of liquid nitrogen cooling systems or stabilised optical platforms, usually needed for optical measurements.

More specifically, the objectives of this WP are to answer the questions – can remote sensing techniques substitute conventional towers with the precision required by the IEC standards, and secondly - how do we best exploit the freedom to measure detailed profiles offered by remote sensing techniques.

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THE RESEARCH ACTIVITIES

PROBLEMS TO SOLVE, BACKGROUND

The work of this WP concentrates on LIDARs, monostatic and bistatic SODARs. Existing work already resulted in examples of both instruments showing their capabilities (determination of power curves using SODARs and LIDARs, site assessment and comparisons with cup anemometer measurements). The intention of this WP is to mature the work, which has already taken place, on the LIDAR and the monostatic SODAR techniques, through a coordinated effort. By the end of the project, the remote sensing methods will be introduced into the existing standards (the relevant IEC and MEASNET documents) as valid alternatives to the existing methods for measuring wind speed and direction. For the bistatic SODAR, the intention is to investigate further into this technique, since the theory shows that it possesses a large potential.

The main research activities of the WP can be summarised as follows:

- A description of Remote sensing of the wind flow in all stages;
- Perform traceable calibrations for the monostatic SODAR and LIDAR's;
- Define improvements on the Monostatic SODAR and the LIDAR;
- Improvement work on Bistatic SODARs
- Measurements including comparisons in flat terrain (monostatic SODAR, LIDAR, met tower, w/t);
- Measurements and inter-comparisons in complex terrain (monostatic SODAR, LIDAR, met tower, w/t);
- Measurements with a LIDAR system mounted on the turbine nacelle in order to measure the near flow field in front of the rotor and measurements in flat terrain.

The work has been divided into 5 different subtasks.

IMPROVEMENTS ON THE MONO-STATIC SODAR AND THE LIDAR

The use of the mono-static SODAR and the LIDAR depends on a number of external factors, which have a direct impact on the availability and the quality of data from each instrument. For the SODAR, rain, echoes from the surroundings, the songs of birds and cicadas are some examples of disturbing phenomena. Improvements are possible by changing the instrument's software. Taking advantage of the differences in the spectra of various incidents in combination with the use of more advanced filtering methods could result in increased availability. Incidents like precipitation, snow and low clouds are known to influence the LIDAR response.

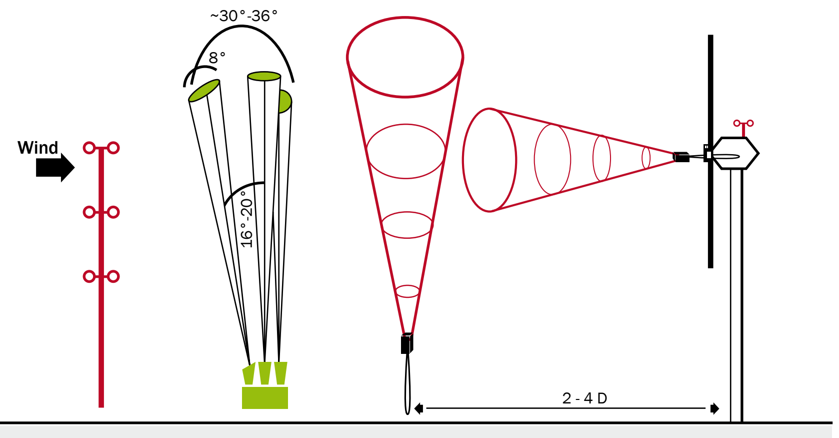
Thus, there is a need to develop corrective algorithms in order to enhance the data availability and reduce the number of erroneous data during such atmospheric conditions. The geometric lay out of the measurement system also needs to be improved or modified. Other possible issues include the scan rate, the FFT size and the number of averaging operations needed to achieve the required accuracy of the results. The measurement results will be tested and verified as part of the following task.

COMPARATIVE MEASUREMENTS IN FLAT TERRAIN (MONOSTATIC SODAR, LIDAR, MET TOWER, WIND TURBINE)

Long-term measurements in flat terrain will be carried out using one SODAR, one LIDAR and a met tower, which is fully equipped with instruments, and preferably located adjacent to a wind turbine. Two LIDAR's will be situated close to each other in order to check the repeatability of the measurements. The power curve of a multi MW wind turbine will be measured simultaneously. The data set will support the flow analysis, which has taken place in other WP's and together with the traceable calibration methods, will be used for the introduction of the remote sensing methods in the IEC Standards for power curve measurements.

INTER COMPARISON MEASUREMENTS IN COMPLEX TERRAIN (MONOSTATIC SODAR, LIDAR, MET TOWER, WIND TURBINE)

Simultaneous measurements will be performed by both a monostatic SODAR, a LIDAR and a heavily instrumented met tower preferably located near a MW size wind turbine in complex terrain. In a second case, comparative measurements will take place between a LIDAR, a met mast and a wind turbine. The goal of the measurements is to enhance our knowledge of problems and pitfalls of using remote sensing measurements in complex terrain. The goal is to present a power curve and a siting measurement technique using the instruments in complex terrain. At a later stage, measurements will take place using either two SODARs or two LIDARs placed close to each other for inter-comparison purposes. During this campaign care will be taken that the same type instruments (SODAR-SODAR or LIDAR-LIDAR) are used while sampling overlapping atmospheric volumes.



WORK ON THE BISTATIC SODAR

In the bistatic SODAR, the two major elements, the transmitter and the receiver, are spatially separated. This makes its deployment more complex since the position of the different parts must be known to high precision. However, advances in satellite positioning systems have largely removed these obstacles. Bistatic SODARs have a number of theoretical advantages over a monostatic system. They receive backscatter not only from temperature inhomogeneities as a bistatic SODAR, but also from velocity fluctuations. Not only does this improve the signal to noise ratio but it also enables the bistatic sodar to measure in neutral conditions where a monostatic system would normally fail. This makes the instrument a potentially attractive alternative to other remote sensing systems. A bistatic SODAR will be designed, built and tested against the SODAR and LIDAR remote sensing instruments and an instrumented met mast. The bistatic SODAR to be built will be combined with a conventional monostatic, phased array option which will allow scanning at different heights and thus produce the wind profile at a certain location.

TURBINE MOUNTED LIDAR

The option to use the LIDAR on the turbine nacelle is investigated. The idea is to take advantage of the information about the upstream wind velocity, which the turbine rotor will experience a short time later. The rotor control system could use this supplementary information for optimising the power production and minimising the loads. The LIDAR output needs to be incorporated in the control system of the turbine. Basic load/power measurement will take place in order to demonstrate the advantages and difficulties of the setup relative to the normal configuration mode.

RESULTS AND EXPECTATIONS

Research carried out so far (two years) has produced the following results:

- The inter comparison between two LIDARS have shown very similar results;
- A new cloud algorithm has been implemented and has improved the quality of the LIDAR measurements in comparison with cup anemometer measurements;
- Power curves, established on the basis of SODAR measurements have been measured with a scatter that is slightly larger than cup anemometers;
- At higher heights, influence from wind shear on the ratio between LIDAR and cup anemometer measurements was observed, which now can be theoretically explained.

Further expectations of the research include:

- An analysis of the inaccuracies and uncertainties of LIDAR and SODAR measurements.;
- A report containing considerations with respect to the acceptance of remote sensing in IEC power performance measurements;
- A description of the principles of the LIDAR calibration method;
- An analysis of the impact of volume integration and sampling frequency on the measurement of the wind speed by both LIDARs and SODARs as compared to the measurements carried out by cup anemometers;
- Measurement of turbulence parameters through remote sensing in both flat and complex terrain. The analysis of the procedure for making turbulence measurements using LIDARs and SODARs will be supplemented with measurements and comparisons with met mast data;
- A comprehensive literature review, field testing work with a new compact bi-static design, design work on reducing horizontally-propagating sound;
- Measurements in flat terrain using a SODAR, a LIDAR and an instrumented met mast in front of a wind turbine Inter-comparison of two LIDARs closely situated next to each other to test traceability;
- Measurements in complex terrain using a SODAR, a LIDAR and an instrumented met mast in front of a wind turbine.
- Measurements in complex terrain using a LIDAR and an instrumented met mast in front of a wind turbine;
- The QinetiQ prototype LIDAR will be placed on a turbine nacelle in order to measure the wind speed in front of the turbine and thereby investigate the possibility of using turbine mounted LIDARs for measuring power curves.