1.0 Introduction
Traditionally, wind data for siting and operation of wind turbines have been collected using cup anemometers and vanes on meteorological towers. Lidar for wind energy deployment uses atmospheric scattering of beams of laser light to measure profiles of the wind at a distance. Task 32 addresses the rapid development of wind lidar technologies and their applicability for more accurate measurement of wind characteristics relevant for reliable deployment of wind energy power systems.

The purpose of Task 32 is to bring together the present actors in the industry and research community to create synergies in the many research and development (R&D) activities already on-going in this very promising and new remote sensing-based measurement technology. The task was approved by the IEA Wind Executive Committee (ExCo) in autumn 2011 and began work in May 2012. In 2013, 42 institutions from 15 countries were involved in the task activity.

2.0 Objectives and Strategy
The main objective of the task is the publication of experimentally-tested recommended practices and expert group reports for wind lidar measurements based on the joint experience of the participants. The recommendations will be benchmarked with measured data collected at various meteorological and lidar operational conditions. Task 32 is only considering lidar systems even though sodar is another promising remote sensing technique that was considered as well in the above-mentioned IEA Wind Topical Expert Meetings.

IEA Wind Task 11 developed and approved the publication in 2013 of Recommended Practice RP: 15. Ground-Based Vertically-Profiling Remote Sensing for Wind Resource Assessment to set the stage for research on remote sensing. This document was also reviewed by participants of Task 32. The further understanding gained in Task 32 will be collected and either summarized in an addendum to RP 15, or included in a second edition of this document.

3.0 Progress in 2013
During 2013, all work packages (listed under subtasks I, II, and III) were begun and the task activity proceeded mainly over teleconference meetings and exchange of documents, papers, and technical reports on a virtual working space. The third plenary meeting was held in May at the NREL National Wind Technology Center in Boulder, Colorado, United States. This meeting was attended with enthusiasm by 33 participants. The progress of each subtask is presented separately in the next sections and then some technology highlights are given for relevant topics of the task.

3.1 Subtask I
Calibration of wind lidars is addressed in this subtask in particular for ground as well as nacelle-based devices and for floating units too. Concerning ground-based vertical profilers, the issue of calibration repeatability of the same device has been studied. In particular two aspects have been considered: different statistical approaches (vector and scalar average) have been compared, as well as the combined effect of the vertical shear, the spatial average along the line of sight, and the accuracy in the sensing range has been investigated (WP 1.1).

For nacelle-mounted lidars, a procedure for their calibration has been proposed (WP 1.3). For floating lidars, experience and information have been collected and an RP is in preparation (WP 1.5).

3.2 Subtask II
RP 15 was presented to the audience during the third plenary meeting and since then feedback has been collected (WP 2.1). During the same meeting the challenges of applying lidar in inhomogeneous flows were addressed. From the discussion, a draft state-of-the-art document has been compiled and is currently under revision (WP 2.2). Within this document, particular attention is given to application of lidar vertical profilers in complex terrain and to application of scanning lidars. An extensive bibliography about the evaluation of turbulence from vertical-profiler's measurements has been collected and reviewed. An outline has been prepared for a group of experts' report which summarizes the collected documents (WP 2.3).
3.3 Subtask III
The indications included in the IEC 61400-12-1 standard concerning the power performance of wind turbines by means of ground-based remote sensing have been applied on the same datasets by different participants. The results provided do not always agree due to ambiguity in the norm, which can lead to different interpretation (WP 3.1).

Knowledge and experience about power curve measurements have been collected and reviewed. This information was used to write the outline for a group of experts’ report that includes the application of different type of nacelle-based lidars as well as different strategies for the evaluation of the power performance of a wind turbine (WP 3.3).

3.4 Technology highlights
The task activity supports diffusion to industry of the advanced applications mainly implemented in the research. In this section, current developments in lidar applications are presented for three different cases.

3.4.1 Offshore met-masts
Floating lidar systems represent a cost-effective alternative to an offshore met mast (opening photo: right). Met masts not only require a significant capital investment but are also limited to smaller heights than those captured by a standard lidar device. Floating lidar also requires a shorter process of permitting than met masts because they have lower requirements for a corresponding marine license application, a significantly smaller disturbance of the environment, and a greater flexibility of the system enabling deployment at different locations.

A floating lidar system is here defined as a lidar device integrated in or installed on top of a buoy. The offshore environment presents major challenges to the lidar instrument but also to the complete system. The harshness of the environment sets requirements on all system components; its non-stability (with changing water depths, wave conditions, and ocean currents) requires certain adaptability; and the limited access by technicians affects the availability and the reliability of the system. Power supply may also be a critical issue, and needs to be ensured by a technically mature approach—similarly as data storage and communication.

Furthermore, the quality of the lidar measurements—in terms of accuracy and precision—is affected by the motion of the buoy. Platform-temporal motions, including up to six degrees of freedom, may cause systematic measurement errors, appearing e.g., as a wrong projection of the wind velocity vector, a confused wind direction measurement, added velocity components, increased lidar turbulence intensity, or a wrong measurement height. The development of suitable and optimized floating-lidar systems for an application in the offshore wind industry has made considerable progress during the last few years. There have been adaptations in lidar and buoy technologies but also in the concepts used for installation or data handling, and in particular the consideration of motion effects on the recorded data.

Several floating lidar systems are meanwhile considered as pre-commercial. The first commercial contracts were signed but the absence of agreed upon standard procedures for their application still prevents the deployment of a large number of devices. The WP 1.5 of the IEA Wind Task 32, comprising system providers as well as independent measurement institutes and consultancies, has now formed to draft a corresponding guideline document aimed to be accepted as an RP in the near future.

3.4.2 Scanning lidars
While the application of wind lidar vertical profilers is getting widely adopted in both industry and research, scanning wind lidars are...
now in the phase of gathering experience. Different from a vertical profiler, scanning lidars do not provide the horizontal wind speed and wind direction as output ready to use; they just provide the line of sight wind component. This, combined with the possibility to steer the laser beam in the desired direction, offers a lot possibilities of measurement and analysis. Some applications have already been developed, e.g., shear mapping, wake measurements, and gust detection.

More sophisticated applications involving two or three scanning lidars are also starting to be implemented in order to combine the line of sight data measured by the available units. With this kind of application, depending on the installation layout and the number of the units of scanning lidars available, it is possible to retrieve the horizontal wind vector over the scanned area. It is also possible to retrieve the flow inclination over complex terrain, or to have a so-called virtual met mast, which can be easily moved over a site. The upper part of Figure 1 shows the measured line of sight of the individual devices. The detail shows the magnitude of the horizontal wind vector evaluated from the measurements at hub height. Spurious and blocked sectors are blanked in gray.

Research is still required to increase the confidence in these new applications, to optimize the strategy of the measurements, and to enhance the related methods of analysis. Nevertheless, technological aspects such as the pointing accuracy also have to be addressed in the future. These points are going to be addressed in WP 2.2, where scanning lidars are included in a list of applications, the so-called “use cases,” next to other wind-lidar devices. Their applications are classified accordingly to their scope, an explanation about their limitations is included, and further guidance is provided.

3.4.3 Nacelle-based lidars

Lidar technology is becoming more and more popular for site assessment purposes (opening photo: left). However, wind not only provides the energy source for wind turbines but also causes disturbances to the control system. Advances in nacelle- and rotor-based lidar technology provide new opportunities to rethink conventional control strategies. Traditional feedback control systems are only able to react to impacts of wind changes on the turbine dynamics after these impacts have already occurred. With the new nacelle-based lidar systems, the information about incoming disturbances can be made available ahead of time. This allows a fundamental reformulation of the control problem. A previously unknown and unpredictable disturbance is partially unveiled and thus can be used for preview control algorithms that incorporate this knowledge to optimize energy production and reduce structural loads.

However, with the lidar technology the incoming wind disturbance cannot be measured exactly. This requires research to address two coupled aspects. On the one hand, the complex wind field can be reduced to wind characteristics such as speed, direction, or shears, and a control problem can be formulated to address changes in the disturbances. In high wind speeds, feed-forward control based on the rotor effective wind speed can assist the blade pitch controller in regulating the rotor speed as well as mitigating structural loads. This can lead to lower operational and manufacturing costs. Approaches improving yaw control and preventing shutdowns due to over-speed are promising for energy optimization.

On the other hand, the performance of the preview controller depends on how well the wind characteristics measured by the lidar correlate with the effective disturbances acting on the turbine. A thorough understanding of the nature of the wind, as well as signal processing and estimation principles, are mandatory for developing accurate measurement techniques that enable successful preview control algorithms.

Pioneering work in this field has been done by scientists from SWE at the University of Stuttgart together with engineers from NREL in Boulder, CO, U.S. In the world’s first test of lidar-assisted control of a wind turbine, they proved the concept and lowered the rotor speed variation of two mid-scale research wind turbines equipped with a nacelle-based lidar systems. However, further investigations are necessary to bring the technology forward to a future, where all wind turbines are able to see and react to the incoming wind changes. Part of this complex matter is discussed within WP 3.2, where different approaches to model the wind are proposed in order to evaluate the wind field characteristic from lidar measurements. Possibly a group of experts’ report will provide indications for the further implementation of nacelle-based lidar measurements for control application.

4.0 Plans for 2014 and beyond

In the upcoming year, two plenary meetings are scheduled. The first one will take place in Stuttgart at SWE-University of Stuttgart in March. The second one is planned to be in autumn in the U.K. During these meetings, results from the WPs will be presented as well as the progress of the expected deliverables. Official information about the task can be found at www.ieawind.org Task 32. The activity of the WPs can be followed at (https://sites.google.com/site/ieawindannex32/home).

References:

Opening photo: Left: Nacelle-mounted lidar (Credit: Wolker-Möhlmann); Right: Floating lidar (Credit: Fraunhofer IWES)

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