Summary of IEA RD&D Wind – 51st Topical Expert Meeting on

State of the art of Remote Wind Speed Sensing Techniques using Sodar, Lidar and Satellites

January 2007, Risø, Denmark

Background
Wind power is moving towards the installation of wind farms in complex terrains, offshore, in forests, and at high levels in the atmosphere. Marketing of large, multi-MW wind turbines is in continued growth. At the same time our basic knowledge on winds in these challenging environments is inadequate.

The method traditionally used for accredited measurements for wind energy purposes is to mount cup anemometers on met masts. As turbines grow in height, mast instrumentation, erection and maintenance have become expensive; prices increase with height and building permits can be time-consuming. At the same time the discrepancies between the measured wind at the rotor centre and the turbine performance have increased the need for determining the wind over the whole turbine rotor.

Successful development of wind power should be based on sound information on winds in each location. To achieve this it is important to place emphasis on new observation methods and strategies. Most promising are the new (for wind energy purposes) remote sensing techniques: Sodar, Lidar and satellite. Sodar is based on sound propagation, Lidar on laser doppler and satellite on microwave scatterometry and Synthetic Aperture Radar (SAR) methods. Advantages and limitations of the various techniques will be described and discussed.

SODAR
Sodar (SOund Detection And Ranging) provides a method for wind speed measurements. The instrument is ground-based and emits a short pulse of sound at a certain frequency to the atmosphere. The sound propagates upwards, while at the same time a part of the sound is reflected back. The Doppler frequency shift of the received signal is proportional to the wind speed aligned to the transmission sound path. By combining three or five of these pulses, usually one along the vertical and two or four inclined to the vertical, the three-dimensional velocity field of both the mean values and the turbulent values is calculated.

LIDAR
Lidar is a remote sensing technique that offers the ability to determine wind speed and direction at substantial heights using a ground-based instrument. In this respect it is similar to Sodar, but operates via the transmission and detection of light rather than sound. The basic Lidar principle is to measure the Doppler shift of radiation scattered by
natural aerosols carried by the wind. Typically, these are dust, water droplets, pollution, pollen or salt crystals. A new generation of fibre-based Lidar has emerged in recent years that operates close to the theoretical limit of sensitivity and typically only needs to detect one photon for every $10^{12}$ transmitted in order to measure wind speed. Since the Doppler-shifted frequency is directly proportional to line-of-sight velocity, the wind speeds obtained by a Lidar instrument seem not to need calibration. This however still remains to be documented by more measurements and by a full description of the whole measurement chain. As in the case of Sodar, the Lidar is also a new instrument, and its merits and limitations are neither fully documented nor known. In the case of the Lidar, the measurement of the wind speed takes place on the surface of a cone where the depth changes as a function of the focus distance. The measurement of the turbulence quantities using Lidar also remains to be documented.

**Satellite remote sensing**

Satellite remote sensing provides wind maps (snap-shot images) of the surface wind at 10 m above sea level. From a scatterometer, twice daily, wind maps at grid resolution of 25 km are available. The data series from July 1999 to present holds more than 5000 observations at most locations of the globe. Due to the resolution of 25 km, observations are not available close to the coastline (usually there is a void around 40 to 50 km distance offshore). In contrast, SAR wind maps cover the near coastal zone in which most wind farms are located. Far fewer SAR wind maps are available (e.g. a few hundred or less), but by using statistical treatment of a few samples, rough estimates of the wind resource can be obtained. The accuracy, around 1.1 m/s standard error, on a series of wind maps compared to offshore mast observations is useful in pre-feasibility studies and in decisions about the location of offshore masts (or LIDAR/SODAR). In addition, if high-quality met-observations are available within a mapped area, the relative differences in winds between different locations can be estimated with higher accuracy, possibly around 0.6 m/s.

**Participants / Presentations**

A total of 51 participants attended this meeting with representatives from Denmark, Finland, Germany, Ireland, Norway, Sweden, the Netherlands, UK and USA. The participants mainly represented National Research Organizations, utilities and entities performing measurements.

The large number of participants in the meeting reflected the interest in this research topic and application in wind turbine work. The number of participants was restricted due to the size limitations of the meeting facilities.

The number of presentations was 29, covering the following subjects:

- General: 8 presentations
- Sodar: 10 presentations
- Lidar: 9 presentations
- Satellite: 2 presentations
Discussion

A discussion was held at the end of the meeting. Some of the discussions are summarized below. These points should not be regarded as “truths” coming out of the discussions, but rather comments that participants gave.

General

- There was a common understanding that there is a need for more experience from remote sensing, especially comparing the performances of Lidar and Sodar.
- Lidar and Sodar will complement each other for a while. Both instruments will have a future in atmospheric science.
- Axel Albers: Both Sodar and Lidar have room for improvements. I researched Sodar since 1992. We never got the reproducibility we now see with the Lidar. The first QinetiQ Lidar give astonishing results. It will take a very long time before Sodar can replace met mast in terms of absolute wind speed. This will soon happen with Lidar.
- Andrew Tindal: For some time to come remote sensing will be used in conjunction with conventional anemometry. But, carefully, we should step towards the replacement, through understanding all the errors.

Sodar

- Sodar are commercially available from a number of different companies. Lidar on the other hand are for sale, but are not as developed and commercialized.
- Sodar are generally cheaper than Lidar. A price tag of the ZephIR is 100.000 GBP. Axel Albers commented that customers asking for measurements are not willing to pay rental for such expensive instruments.
- Sodar has fundamental limitations compared to Lidars. The wave length of the sound is large compared to that of light, implying bulkier sodar instruments. The speed of sound is much smaller than that of light, implying that the sound ray propagation in the atmosphere is considerably more complicated, e.g. beam drift. Given the recent development some argued that Lidar has a brighter future than that of Sodar.

Lidar

- Lidar has the disadvantage that the averaging volume increases with height, whereas the corresponding volume for the Sodar remains constant with height. Maybe the pulsed lidar technology will change that.
- Hans E. Jørgensen pointed out that we need to test the performance of Lidar in complex terrain: wind shear, turbulence intensity and flow inclination are issues here of great interest for developers.
- Troels Friis Pedersen: I believe a Lidar mounted on nacelles will be extremely useful for power performance measurements. Stefan Emeis: Maybe there is a difference in the needed accuracy between siting and power performance measurements. Sodar may be fine for wind profiles. J. Højstrup strongly
disagreed. We always need the same accuracy. Better accuracy implies lower financial and technical uncertainties. Albers: There are still a lot of uncertainties in site assessment.

Satellites

- Satellites always see the structure of the surface, e.g. SAR see the wind stress on the surface. Models are needed to transfer this information to hub height. Given the accuracy needed it may not be worthwhile.
- Space-borne Lidar are coming and they may be useful.
- Neil Douglas (Natural Power Consultants): Maybe accuracy is not always so important. For example satellites may be used for relative resource estimation.

There is a need for “best practices” on how to use remote sensing as siting devices, etc., as suggested by Kathleen Moore. More sodar /lidar/mast comparison needs to go to the literature. The initiative of Risø of a remote sensing test facility at Høvsøre is good!

Continuation

There was a common understanding that there is a need for more experience from remote sensing in order to increase the accuracy and the repeatability of measurements, especially comparing the performance of Lidar and Sodar with anemometers. The IEA-developed Recommended Practices for anemometry are available and could be used as a reference for developing similar documents for Lidar and Sodar. Participants pointed out that such documents are needed in a near-future time frame.

As a first step of continuation it was considered relevant to undertake initial work related to develop such practices. It was agreed to form two Ad-Hoc groups to put together proposals for the proper operation of a Sodar/Lidar. The ad-hoc groups should make to-do lists for improvements of the instruments.

- Sodar group: Kathleen Moore will take the lead. Participants: Gunter Warmbier, Mats Hurtig, Andy Oldroyd, Finn Nyhammer, Brian Hurley, Peter Clive, Sabine vonHunerbein, Ken Underwood, Stuart Bradley
- Lidar group: Ioannis Antoniou will take the lead, Axel Albers, Ian Locker, Detlef Kindler, Andreas Rettelmeyer, Brian Hurley

It was noted that there exists a general recommended practice for remote sensing. One in Germany (VDI 3786 Part 14, Verein Deutscher Ingenieure, Environmental meteorology, Ground-based remote sensing of the wind vector. Doppler Wind LIDAR, Dec. 2001) and elsewhere.

The results from the Ad-Hoc groups will be reported at the upcoming meeting of the IEA Wind Executive Committee by the Operating Agent of Task 11. This may result in further action within this field.