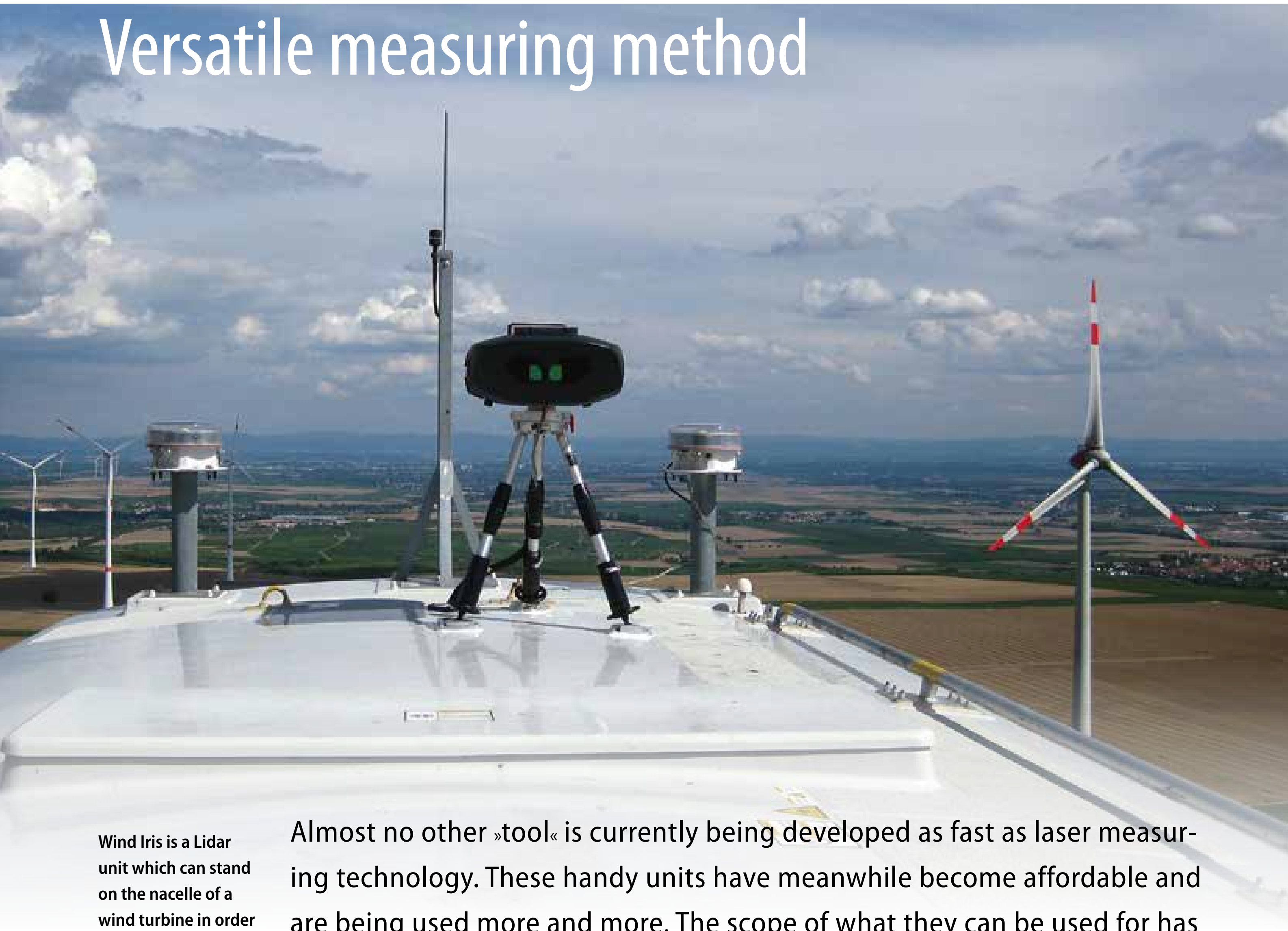
Versatile measuring method



Wind Iris is a Lidar unit which can stand on the nacelle of a wind turbine in order to make forward-looking horizontal measurements.
PHOTOS (2): GWU

Almost no other »tool« is currently being developed as fast as laser measuring technology. These handy units have meanwhile become affordable and are being used more and more. The scope of what they can be used for has not been exhausted either.

The measuring principle is simple and provides huge amounts of data. A laser beam shot into the sky hits aerosols and dust particles which dissipate it. Although only a small portion of the laser light finds its way back to the measuring unit, this is enough to analyse the movement of the particles and calculate the wind speed.

The light reflected back from the particles undergoes a shift in frequency, known from acoustics as the Doppler Effect and which is fairly easy to understand. What is much more difficult is the analysis of the huge amounts of data, which thus requires powerful computers. The wind speed can be calculated from the frequency shift and the timing of the light signal gives the distance to the measuring point, mostly the height of the measuring point above the ground. This distance calculation is no easy matter, for the light only takes a microsecond to travel to a point 150 m away and back again. The quality of the measurement thus depends crucially on precise measurements and data analysis.

Steady stream of measurement values

The good old cup anemometer provides approx. one measurement value per second, while "Light Detection and Ranging" (Lidar) creates a steady stream of 30,000 measurement values in the same period. It has only been since the advent of extremely fast computers which can fit into an easy to handle unit that the Lidar tool has matured to become suitable for mobile wind speed measuring on land, water and in the air.

Until a few years ago, Lidar units were still manufactured in very small series, thus making them almost unaffordable for the wind power sector. The growing demand, also from meteorologists, climate scientists and environmental protection agencies, led to a sharp drop in prices. Over 1,000 Lidar units are meanwhile available around the world and can be hired for measurement campaigns.

"One big advantage of the Lidar measuring method is the high availability of data, with the usual weather-dependent limitations, however," says Ludwig Wagner, Head of GWU-Umwelttechnik. Heavy rain, for example, provides data which is a lot less usable, but you naturally always have to take weather-dependent limitations into account as well when using cup or propeller anemometers, ultrasound anemometers or Sodar. "These are atmospheric disturbances which you cannot avoid," adds Wagner, "but Lidar technology is the one with fundamentally the fewest associated limitations."

Lidar measurements are still not exactly cheap, but their usefulness is such that the investment is worthwhile for many users. They principally value the wide range of opportunities. Lidar units stand for months on end at selected sites to measure the wind potential and calculate the forecast yield of a planned wind farm. They measure the vertical wind profile above a site from 30 to 150 m up. Or they are placed on the nacelle, where they measure the two-dimensional wind field aHead of the rotor. The large range of the laser beam even allows for measurements at a site several kilometres away.

Given the almost unlimited opportunities, the sector was impatient for recognition of the Lidar measuring method by the International Electrotechnical Commission (IEC). This is because approval of the Lidar method by the IEC for the economically extremely important measurement of the power curve is necessary for manufacturers to be able to carry out considerably easier norm-compatible measurements. Norm IEC 61400-12-1 describes the measurement of the power curve with Lidar.

The long wait for the new norm

"The final draft was published on 4th November," reports Axel Albers, Head of Deutsche WindGuard GmbH: "now the national committees must vote on it." However, they can only vote with a yes or no. Amendments to the text are no longer possible. A mast still has to be erected, as the norm requires a reference measurement with a cup anemometer at the lower edge of the rotor swept area. A measuring mast of the same height as the tower, which

The Leosphere Windcube 200S enables horizontal Lidar measurements at a distance of 6 km with a resolution of 50 m.

becomes ever-more expensive with increasing hub heights, will no longer be required, though. This is what achieves the main cost saving.

But the mills of norms grind slowly. This is true not only for the process of setting norms, but also for replacing the old measuring method with the new one. Mathias Hölzer, Head of ProfEC Ventus, reckons on a transition period of two to three years. It will, after all, be several years before new wind turbines are remeasured according to the new norm. "Certification measurements will naturally be carried out using the new norm right away, but experience shows that is is several years before these turbines come onto the market." Wind turbines developed years ago but which are still in production will presumably still be measured according to the old norm. It is only likely to be in a few cases where it will be worthwhile to carry out a new certification for such turbines.

More accurate wind direction measurements

The record from several years of experience with various Lidar systems is impressive. The measuring method is reliable, very accurate and can be used on land and on water, at ground level or on the nacelle. "A Lidar system is a multi-faceted tool in the field of remote measuring technology," concludes Wagner.

Naturally the measurement of wind direction is also possible using Lidar. This is urgently required, for it is only rarely that all the turbines in large wind farms end up facing the same way. The turbines can only measure the wind direction inexactly because the measuring unit is on its nacelle, i.e. in the turbulent down-stream field behind the rotor. Deviations from the correct alignment not only cost kilowatt hours, but can also add to loads on the drivetrain.

Lidar promises to help here in that it measures horizontally "upstream" from the nacelle. The latest generation of nacelle-based Lidar units uses four laser beams (two are angled upwards and downwards at 5°, two further ones at 15° to the left and right) and thus covers a larger measuring area. A numerical model projects the measurement results to the hub height.

Limits of the measuring method

The jubilation on the opportunities from measurements with a laser beam is only dampened by a few negative aspects. "The Lidar unit measures at different points spread out across a relatively wide volume and then calculates the velocity vector from the radial speeds measured at these points," explains Mathias Hölzer and adds: "the current Lidar measurement technology assumes a homogenous wind field, which limits the areas of application." In densely forested, hilly or even mountainous terrain, the currents of wind are anything but homogenous.

A few manufacturers have recognised the problem and developed algorithms to take the complexity of terrain into account. One such unit is supplied by Avent, for example. "Their algorithm has not yet been documented and published to an extent which makes it possible to give a final verdict on this, however," says Hölzer. It is clear that not each measurement system is equally good for all topographies. You always have to take into account the limiting factors and possible uncertainties.

Dreams of the future

To overcome the limits of the conventional Lidar system, the German National Testing Authority – Physikalisch-Technische Bundesanstalt (PTB) – is currently testing a bistatic Lidar system consisting of four individual Lidar units. Three receiver units are grouped around a transmitter unit in such a way that all the units can focus on a small measurement volume. This is why the measurement volume of the bistatic system is only 0.5 m deep, while the conventional system creates a measurement volume approx. 20 m deep. The PTB expects measurement results at a hitherto never-seen level of accuracy. Harald Müller, Head of the PTB working group, even thinks it may be possible to determine the velocity vectors of individual aerosols, so that inhomogeneities within the flow field cannot distort the measurements. A simultaneous determination of all velocity components would enable a higher time resolution and a high local resolution of the spatially tightly restricted measurement volume. But this is still a dream of the future, let alone what the costs would be. However, the example does show what the future has in store for us. The Lidar measuring method is nowhere near exhausting its potential.

Detlef Koenemann

Measuring ahead of the spinner

Although it has long been known that wind speeds directly behind the rotor cannot be measured exactly because the downstream currents distort the measurements, all wind turbines built up to now have routinely been fitted with anemometers, which are placed on the roof of the nacelle. The reason for this is simple; until now there has been no alternative.

But things have now changed. The company Romo Wind installs three specially shaped ultrasound anemomenters on the rotor spinner which measure the speed of the wind flowing past the spinner. The "iSpin technology" was developed by the Technical University of Denmark (DTU) and tested for several years. Romo Wind, together with Vattenfall, has recently studied at the Danish wind farm Nørrekær Enge how power curves measured using different methods differ from oneanother.

A comparison of measurements made using an IEC-compliant measuring mast, a nacelle-based Lidar system and the iSpin system showed that the spread of measured values away from the power curves is lowest when measured using the iSpin system. You have to take into account, however, that the spinner also distorts the wind stream. A transfer function has thus been determined for each wind turbine type in order to be able to calculate the undisrupted wind speed.

"When we measure a new turbine type, we take the nacelle design and the blade design into account by comparing the results with measurements made using a wind measuring mast or a Lidar campaign," explains Jens Müller-Nielsen, Head of Romo Wind Deutschland GmbH. After determining the error in the nacelle alignment and a corresponding correction, a significant yield improvement can be seen. Müller-Nielsen speaks of 2 % higher yields and adds that turbulence intensities and currents off at an angle can also be determined using the iSpin technology.