INNOVATION

Research & Development • Design & Engineering • Forecasting & Analysis
Consultancy • Certification & Standards • Efficiency • Emerging Technologies

Achieving quality by calibrating remote sensing devices

Figure 1: Calibration test field of Deutsche WindGuard. Left: Enclosure with tested LiDARs in front and the base of the 135 m high reference met mast in the back. Right: Wide shot of the reference mast from a view angle opposite of the one on the left.

By Klaus Franke
Deutsche WindGuard GmbH

Recent years saw the advance of remote sensing devices (RSD) for measuring wind speed and wind direction in the wind energy sector. Depending on whether an RSD uses either laser or sound technology, the instruments are called LIDAR (LIght Detection And Ranging) or SODAR (SOund Detection And Ranging), respectively. Compared to traditional met masts, these units are easy to install and have a measurement range up to 200 meters — all without needing a building permit.

Trailing behind this rapid development are the manifestations of internationally accepted standards in the industry with regard to the quality of remote sensing measurements. The development is centered on the revision of the IEC 61400-12-1, ed. 2 [1]. The current version of this standard from 2005 defines the requirements on the usage of cup anemometers in the industry. The revision will likewise define procedures on accuracy assessment of RSDs. The core elements are:

- Calibration of the used RSD;
- Classification of the used type of RSD;
- Monitoring during the measurement; and
- Complete assessment of the uncertainty of RSD measurements

The calibration of every unit used is necessary to achieve traceability to national standards. Due to their large measurement geometry spanning up to a hundred meters, RSDs cannot be calibrated in wind tunnels. Therefore, a calibration is performed against a conventional met mast equipped with traceably calibrated cup anemometers. Figure 1 depicts the RSD test field of Deutsche WindGuard (DWG) in Northern Germany. The 135-meter-high mast is equipped with cup and sonic anemometers and wind vanes every 20 meters.

Deutsche WindGuard regularly performs calibrations of different RSDs on this test field. Some of the results gained in these calibrations will be presented in this article. In order to illustrate the need for these measurements, DWG made two comparisons. One is between instruments of the same type and one between instruments of different types.

Figure 2 summarizes the results of the calibrations of four LIDAR units of the same type, but of two different series of this type. Shown are the deviations between wind speed measurements made by the RSD and those made by the reference instruments on the mast. All four calibrations were made in the same measurement period with the instruments positioned close to

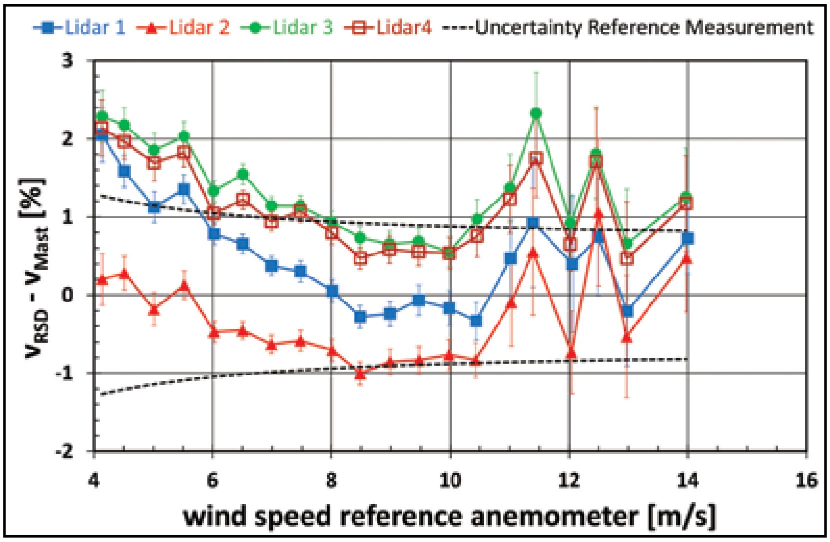

Figure 2: Comparison of four lidars of the same type . Shown is the relative deviation between lidar and mast measurements made during concurrent time periods. Errorbars show the statistical uncertainty in the given values.

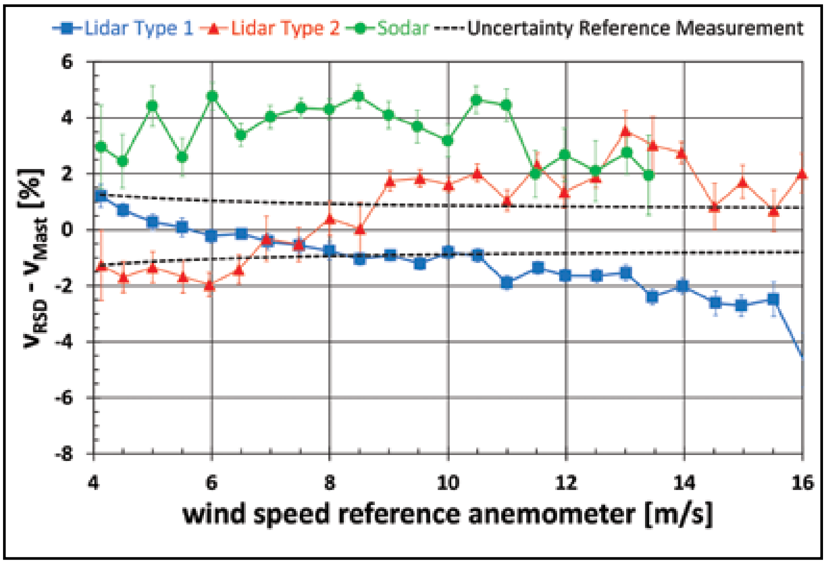

Figure 3: Comparison of three different types of RSDs. Shown is the relative deviation between RSD and mast measurements made during similar time periods. Errorbars show the statistical uncertainty in the given values.

each other; therefore the differences in the results are directly linked to the accuracy of the individual units. Units 3 and 4 are of the same series of the instrument and show the same behavior with significant overestimation of wind speed at lower wind speed. Compared to these two LIDARs, the other two units give lower wind speeds at the same measurement points.

Figure 3 shows a similar comparison between different RSD types, two LIDARs and one SODAR. Compared to the four LIDARs represented in Figure 2, these show more significant over- and/or underestimations of wind speed of several percent higher than the uncertainty of the reference measurement. Each unit was subject to the manufacturer's factory check prior to calibration. These results clearly show that RSDs cannot be used out of the box without proper establishment of traceability.

The impact of the observed deviations can be illustrated by the application of these results. One main field of application of LIDARs and SODARs are wind resource assessments. Annual energy productions (AEP) are estimated from the measured wind speed distribu-

RSD	AEP_{RSD} - AEP_{Mast} [%]
Lidar 1	0.6
Lidar 2	-1.0
Lidar 3	2.0
Lidar 4	1.7
Lidar Type 1	-1.0
Lidar Type 2	0.3
Sodar	7.1

Table 1: Difference in terms of Annual Energy Production (AEP). RSD units are the same as in Figure 2 and 3. Used is an annual average wind speed of 6.5 m/s and a turbine with 300 W/m².

tions. This is done by applying these wind speed distributions to power curves of the planned wind turbine. For example, the AEP is calculated for an annual mean wind speed of 6.5 m/s for a turbine with a rated power of 300 W/m². Table 1 summarizes the difference in AEP relative to an AEP estimated from mast measurements for the seven calibrated LIDAR and SODAR units represented in Figures 2 and 3. The four units of the same LIDAR type shown in Figure 2 differ between -1% and +2% in AEP from mast measurements. The units shown in Figure 3 differ by up to 7 % in AEP from a mast measurement.

These results emphasize the importance of calibration of applied RSDs. Although some units can achieve realistic energy yield estimations, this is not necessarily the case for every unit. Depending on the units used, a difference of up to 7% in estimated energy yield is measured. This difference is much too high, considering that the expected energy yield has a direct impact on the value of a project. Sufficient confidence in the wind measurement can only be gained through calibration of the RSD.

Taking that fact into consideration, two further problems arise. The first is that the calibration is made at a different site, and possibly during a different season, than at the application site. Thus, the atmospheric conditions can vary significantly between calibration and application. Since the measurement accuracy of RSD units can depend on environmental variables like turbulence intensity or wind shear, the draft of the upcoming revision of IEC 61400-12-1, ed. 2 [1] establishes a procedure to quantify the sensitivity of RSDs on environmental variables called classification.

The classification procedure analyzes the measured difference between an RSD and a met mast in dependence of environmental variables like wind shear and turbulence intensity. This results in a sensitivity factor for each variable that quantifies the change in accuracy with a change in this variable. To give an example, we will assume that the accuracy of the LIDAR changes by 2% when the wind shear exponent changes by 1. If such a unit is calibrated with an average wind shear exponent of 0.1 but during the application an average wind shear exponent of 0.2 is observed, an additional uncertainty of 0.2% in wind speed has to be considered in the uncertainty budget.

The second problem is to ensure that the calibration of the unit is valid for the complete measurement, i.e. that there is no drift in instrumental accuracy. The revision draft of IEC6140-12-1 ed. 2 requires that the LIDAR is monitored by a short met mast during the application. With this mast, the verification test is repeated for the common measurement height of the mast and the RSD. If increased deviations between the mast and LIDAR are observed in this second verification, this can be taken as additional uncertainty. As an alternative to the monitoring with a met mast, the German technical guideline TR6 [2] allows monitoring of the measurements being replaced by a second calibration after the application measurements.

The foundation for high quality measurements is laid by following this procedure. During the application, further precautions have to be taken. In particular, the increased measurement uncertainty in complex terrain has to be considered by combining a well-planned position and orientation of the RSD with a sophisticated uncertainty analysis and a potential correction.

In conclusion, high quality wind speed and wind direction measurements can be achieved with RSD's, as long as they are carefully planned, prepared and performed.

References:

[1] Commentary Draft IEC 61400-12-1, ed. 2Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines, June 2013

[2] FGW, Technical Guideline Part 6, Determination of the Wind Potential and Energy Yields, Revision 9, September 2014

For more information, contact WindGuard North America at (571) 331-7927, or visit them online at www.windguard.com.