What makes a nacelle mounted lidar a suitable tool for power performance measurement?

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Nacelle lidars are attractive for offshore measurements since they can provide measurements of the free wind speed in front of the turbine rotor without erecting a met mast, which significantly reduces the cost of the measurements. Nacelle mounted pulsed lidars with two lines of sight (LOS) have already been demonstrated to be suitable for use in power curve measurements [1]. To be accepted as a validated tool however, power performance measurements performed using these instruments require traceable calibrated measurements and the quantification of the wind speed measurement uncertainty. Here we present and demonstrate a procedure answering these needs.

Uncertainty in lidar wind speed measurement

The lidar was installed on a 9m high platform in order to calibrate the wind speed measurement. Each of the lidar’s radial wind speed measurement was compared to the wind speed measured by a calibrated sonic anemometer, projected along the LOS direction [2]. The various sources of uncertainty in the lidar wind speed measurement have been thoroughly determined:

<table>
<thead>
<tr>
<th>Uncertainty in wind speed measurement of the reference sonic anemometer</th>
<th>Uncertainties</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sonic calibration (wind tunnel calibration)</td>
<td>0.035 m/s</td>
<td></td>
</tr>
<tr>
<td>Sonic operational (assuming comparable to a cup anemometer)</td>
<td>0.015 m/s + 0.15%</td>
<td></td>
</tr>
<tr>
<td>Sonic mounting</td>
<td>0.25%</td>
<td></td>
</tr>
<tr>
<td>Sonic flow distortion</td>
<td>0.05% per ±10°</td>
<td></td>
</tr>
</tbody>
</table>

The sonic wind speed was projected to the lidar LOS direction.
Reference wind direction measurement: 0.02% per ±10°
The azimuth direction of the LOS is determined from data analysis.
Lidar LOS direction: 0.1%
The lidar beam must point at the same height as the height of the reference sonic anemometer.
Lidar LOS elevation: 0.2%

The radial wind speed measurement uncertainty for each LOS was obtained by combining in quadrature the uncertainties identified in the table above to the radial wind speed mean deviation and standard uncertainty. The lidar horizontal wind speed uncertainty results from the combination of the uncertainty of the two radial wind speeds. The uncertainty in the lidar horizontal wind speed measurement was found to be in the range 1% to 3%.

References


Method

After calibration the lidar was mounted on the nacelle of a wind turbine in order to perform a power curve measurement [3]. The wind speed was simultaneously measured with a mast-top mounted cup anemometer placed two rotor diameters upwind of the turbine.

Uncertainty in power curve

An uncertainty was added to wind speed bins for which the measurement height was outside the range.

Combined category B uncertainty in wind speed for the power curve measured by the mast mounted cup anemometer (black) and with the lidar (red).

Total uncertainty in the power curve measured by the mast mounted cup anemometer (black) and with the lidar (red).

Conclusions

A nacelle lidar can be a very good tool for power performance assessment, on the condition that the instrument is first calibrated and all the uncertainties are accounted for. Both a calibration procedure and power curve measurement procedure fulfilling these demands for a two beam nacelle lidar have been designed and tested. We have demonstrated that a nacelle lidar is a serious and highly competitive tool for performing power curve testing.

Acknowledgements

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