Wake measurements of a multi-MW wind turbine with long range lidar

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Introduction

Long range Doppler lidar (LIDAR-Light Detection and Ranging) measurements were carried out at a site near the coast-line in Bremerhaven. A 5 MW wind turbine of the type Multibrid M5000, which is the prototype for the first German offshore wind farm “alpha ventus”, is located there. The aim of the measurement campaign was to get information about the ambient wind field of this turbine. The characterization of the wake of the wind turbine was a matter of particular interest. Here we present the measurement setup and preliminary results.

Measurement technique and experimental setup

Lidar is a remote sensing technique where a laser beam is transmitted into the atmosphere and the backscattered light is detected. This provides information about the line-of-sight (LOS) component (component in beam direction) of the wind vector. For the measurements presented in this abstract a 2 µm pulsed Doppler lidar based on the transceiver unit of a MAG-1 instrument of CLR Photonics was used [1]. This laser system has been modified by the DLR and successfully used for wind and turbulence measurements from the ground, as well as from the research aircraft, in the past [2]. Different scan patterns at variable scan speeds are possible. The measurement range is between 500 m and more than 10 km. The main parameters of the 2 µm pulsed Doppler lidar are summarized in Table 1.

Slave laser (Tm:LuAG)	
Wavelength	2.022 µm
Repetition rate	500 Hz
Pulse energy	1.5 mJ
Pulse length	0.5 µs
Telescope	off-axis type aperture: 10 cm
Scanner	double wedge with variable speed
Measurement range	500 m - >10 km

Table 1: Main parameters of the 2 µm pulsed Doppler lidar.

The 2 µm lidar was mounted in a container and placed on a field in a distance of about 1850 m away from the Multibrid M5000 wind turbine. Two scanning techniques to analyse the wake of this multi-MW turbine were carried out: elevation scans (Figure 1(a)) and azimuth scans (Figure 1(b)). For the elevation scans the azimuth angle of the laser beam was kept constant whereas the elevation angle was varied. For the azimuth scans the elevation angle was always the same but the azimuth angle was changed. This results in a scan almost parallel to the ground at a distance of 1850 m because elevation angles did not exceed 5 °. The scan patterns are illustrated in Figure 1. In this figure it can also be seen that there are a lot of other wind turbines in the measurement terrain. Effects of these turbines can be observed in our measurements as well.

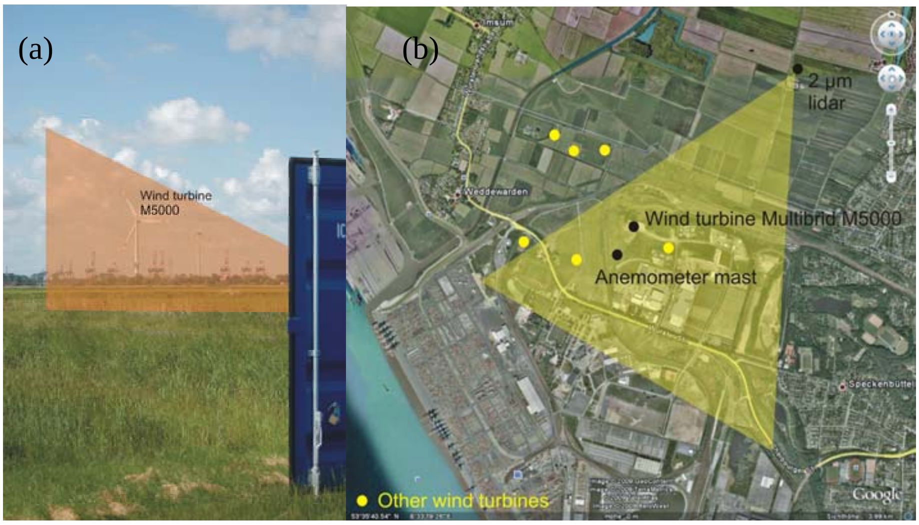

Figure 1: (a) Elevation scan in the wake of the Multibrid M5000. (b) Top view of azimuth scan.

Results

Figure 2 shows the line of sight wind speed depending on width and range of an azimuth scan with a constant elevation of 3.3 °. The azimuth angle was between -8 ° and 22 ° which corresponds to an expansion in width of about 1300 m at a distance of 2.5 km from the lidar. The 2 µm lidar is located at a range of 0 and the Multibrid M5000 wind turbine at a range of 1850 m. This means that the scan proceeds along a horizontal axis 5 m above hub height of the 5 MW wind turbine through the rotor blades. For a better illustration the position of the wind turbines is marked in Figure 1. Multibrid M5000 is, as already mentioned before, located at a distance of 1850 m and at a width of 0 (M5000-1). The second wind turbine implied in Figure 2 at a range of 1850 m and approximately 200 m width is another wind turbine of the same type as Multibrid M5000 (M5000-2). The wind was blowing from southwest direction (compare Figure 1(b)).
There can clearly be seen a velocity reduction in the wake of the wind turbines. After more detailed analysis it is found that this reduction is about 50 %. The length of the wake in this scan is more than six rotor diameters (one rotor diameter = 116 m). Besides the wakes of the two Multibrid wind turbines there can also be seen a smaller wake at a range of 2200 m and a width of about -150 m. This is the wake of another wind turbine in the measurement terrain which is of another type and can also be seen in Figure one. The measurement shown in Figure 2 was carried out during daytime and at a high level of turbulence. Because the

atmospheric boundary layer is much more stable at night than during the day there were also done measurements after sunset to be able to distinguish between turbulence in the atmospheric boundary layer and turbulence induced by the wind turbine. Besides the measurements first trials were made to compare the data with the FLaP model [3].

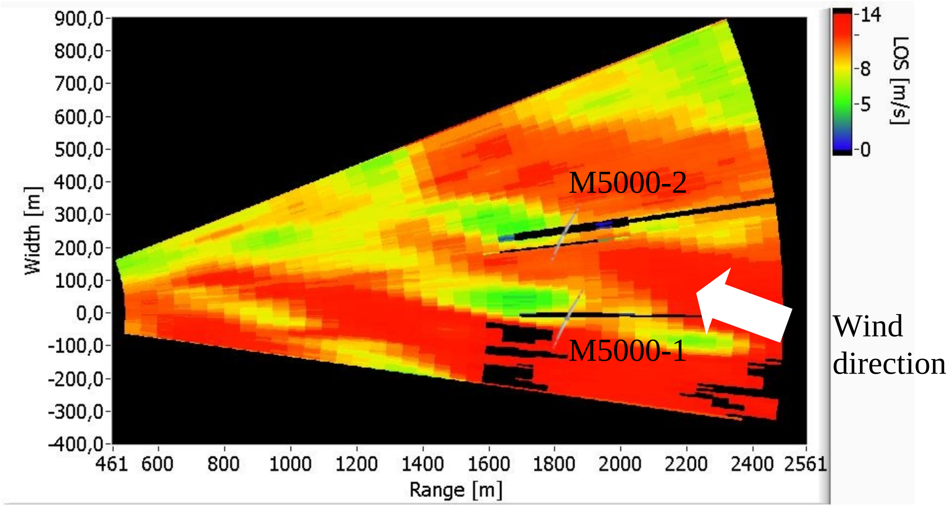

Figure 2: Line of sight wind speed of an azimuth scan like illustrated in Figure 1(b) during daytime, depending on width and range.

Conclusions

Successful field measurements of the ambient wind field of a multi-MW wind turbine were performed with a ground based long-range lidar. These measurements provide a good possibility for comparison with wake models.

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Keywords: wake measurements, wind lidar, long range lidar, multi-MW wind turbine.

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