Development of Lidar wind measurement techniques

Andreas Rettenmeier
Stuttgart Wind Energy (SWE) - University of Stuttgart
RAVE 2012 Bremerhaven, 8.-9.5.2012
Table of Contents

- Motivation
- The projects and their aims
- Project partners
- Lidar systems
- Ground-based measurements
- Nacelle-based measurements
- Conclusions & Outlook
Motivation: Lidar technology
The new quality in wind measurement

Site evaluation & wind potential analyses
- Onshore: „complex terrain“, forest
- Offshore

Turbine development & research
- Higher temporal and spatial resolution of the wind field
- Power curve determination over the swept rotor area
- Loads, wake from other turbines
- Control (fatigue and extreme loads)
<table>
<thead>
<tr>
<th>The projects and their aims</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LIDAR I project (2007-2010)</strong></td>
</tr>
<tr>
<td>- onshore -</td>
</tr>
<tr>
<td>• Lidar measurements ground- and nacelle-based</td>
</tr>
<tr>
<td>• Development of Lidar scanner</td>
</tr>
<tr>
<td>• Wake, p-v and control applications</td>
</tr>
</tbody>
</table>

**OWEA project (2008-2011)**
- offshore -
| • 2 scanning Lidar devices offshore |
| • Nacelle-based Lidar measurements |
| • Comparison with FINO I data |
Project partners within LIDAR, LIDAR II & OWEA

Research Institutes
• Stuttgart Wind Energy (SWE) - Universität Stuttgart
• ForWind - Carl von Ossietzky Universität
• DLR: Institute of Atmospheric Physics

Measurement Institutes
• DEWI GmbH: German Wind Energy Institute
• Germanischer Lloyd Garrad Hassan

Wind turbine manufacturer
• AREVA Wind GmbH
• REpower Systems SE

Dissemination
• FGW e.V.: German Federation of Windpower
Ground-based Lidar measurements

SWE – Stuttgart Windenergie, Universität Stuttgart

ForWind – Universität Oldenburg

DLR- Deutsches Zentrum für Luft- und Raumfahrttechnik e.V.

DEWI GmbH

AREVA Wind GmbH
Lidar Systems

Windcube™ system from Leosphere™

- Range: 40m – 220m
- Wavelength: 1.54 µm
- Pulse length: 26m
- Pulse energy: 10µJ

[Fig. Leosphere, DLR]

DLR long-range Lidar

- Range: 500 m - 10 km
- Wavelength: 2.022 µm
- Pulse length: 75 m
- Pulse energy: 1.5 mJ

[Fig. Leosphere, DLR]
Lidar-Test in Bremerhaven and at FINO 1

AREVA Wind GmbH M5000 prototype
• Rated power: 5 MW
• 116 m rotor diameter
• 102 m hub height

Measurement project
• April 2008 – March 2010
• Power curve and load measurement
• Met mast (102 m height)
• Meteorological sensors
• Data acquisition system
• Lidar device (ground, nacelle)

• Location: FINO1 platform
• Period: August 2009 - July 2010
• up to 44,190 10-min. data sets
• Resolution:
  • 10-min
  • 10 Hz (0.1 s) [FINO1]
  • ~0.83 Hz (1.2 s) [LIDAR]
DLR long-range Lidar Measurements

- Results of elevation scans
- 3km measurement range
- Low-Level-Jet determination
Nacelle-based Lidar measurements

SWE – Stuttgart Windenergie, Universität Stuttgart

ForWind – Universität Oldenburg

DEWI GmbH

Germanischer Lloyd – Garrad Hassan

AREVA Wind GmbH

REpower Systems SE
Motivation

Reasons for developing nacelle-based Lidar measurement techniques
• Increasing hub heights and rotor diameter of wind turbines
• Cost expansive certification procedures
• For on- and offshore purposes

Nacelle-based Lidar wind field measurements taking into account
• Whole swept rotor disc
• Wind direction (slow variation) → yaw correction
• Horizontal wind shear, vertical wind shear (fast variation)
• More free valid measurement areas (acc. IEC 61400-12-1)
  → Less sectors to exclude
  → Faster measurement campaigns (on- and offshore)

➔ Measuring the incoming wind for
  • Wind turbine certification
    • Power performance testing
    • Load validation
    • Predictive control strategies

➔ Measuring the turbines wake wind for
  • Validation of wake models
Development of a Lidar Scanner

- Scanner and control software developed by SWE (within LIDAR project)
- Designed for nacelle-based applications
- Adapted to Windcube by AventLidar Technology
- Allows steering the laser beam in any direction
- Proof-of-concept demonstrated in various measurement campaigns on- and offshore (Bremerhaven, Risø DTU, NREL, Alpha-ventus)
Development of a robust Lidar

- Under development, by Forwind-Oldenburg (within LIDAR II project)
- Designed for nacelle-based applications
- Proof-of-concept demonstration onshore and offshore at alphaventus (planned)
Experiment setup - Bremerhaven

LIDAR system installed on the nacelle (May 2009 - March 2010)
REpower 5M & AREVA Wind M5000 – inflow and wake
Power curve determination and Statistical Load Estimation

[Fig. SWE]

Rettenmeier et al.
Development of LIDAR wind measurement techniques
Rave International Conference 2012
Results of nacelle-based near wake measurements (AREVA M5000, AV7, alpha ventus)
Conclusions & Outlook

• Development of a scanning Lidar system
• Development of wind turbine applications using a Lidar for
  • power curve determination (ground- and nacelle-based)
  • wind turbine control (predictive control strategies)
  • wake wind field analysis (wake modelling and measurement)
• Offshore test of Lidar device on FINO 1
• Lidar measurements on two offshore wind turbines in “alpha ventus”,
• Further development and test of robust Lidar device
• Proof-of-concept of predictive control
Thank you for your attention!

Feel invited for further presentations on Lidar technology

Session 5: Wind turbine control and wind farm flow

5.1 Lidar-assisted wind turbine control
Project: RAVE - LIDAR, RAVE - LIDAR II
D. Schlipf et al., Stuttgart Wind Energy (SWE), University of Stuttgart

5.5 Analysis of wake-induced wind turbine loads
Project: RAVE - OWEA
J.J. Trujillo, B. Kuhnle, H. Beck, ForWind - University of Oldenburg

Session 6: Site conditions

6.4 Statistics of extreme wind events and power curve monitoring
Project: RAVE - LIDAR, RAVE - OWEA
Dr. M. Wächter, ForWind - University of Oldenburg