Testing floating LiDARs offshore
as a prerequisite for a cost-efficient wind resource assessment[1]

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Summary

Floating LiDAR systems gain more and more in importance for the realisation of cost-efficient offshore wind resource assessments (WRA). These kinds of systems may not only offer measurement data that are more complete than those from present offshore meteorological masts (by adding e.g. further measurement heights due to the used LiDAR technology) but have also significant advantages in terms of the associated costs for the provision, installation and final removal of the devices.
Before applying a floating LiDAR system within an offshore WRA campaign, its performance needs to be tested and verified according to a well-defined scheme. In addition to the measurement accuracy the expectable system and data availability is a crucial outcome of a test preliminary to the final application. Guidelines for such testing are underway – with an early document initiated by the Carbon Trust and already presented in 2013, and a more detailed draft document presently prepared within the IEA Wind Annex 32.
To illustrate the guidelines we consider here a particular case study with the Fraunhofer IWES Wind LiDAR Buoy that was first introduced in 2013 and since then tested in two offshore measurement campaigns. Both campaigns confirm a very good measurement accuracy – in terms of correlation to the reference measurements – of the system. We present in detail how the arranged tests follow the drafted guidelines and how the measurement performance of the investigated system is deduced from the collected system and reference data. As test site we have used the FINO1 measurement mast and infrastructure in the German North Sea that has proven to be a suitable reference site for floating LiDAR offshore tests.

Introduction / Motivation

Floating LiDAR technology, defined by a LiDAR device integrated in or on top of a floating platform, has been successfully introduced in the offshore wind industry during the last few years. Particular benefits have been identified for an application within Wind Resource Assessment (WRA) campaigns in terms of the possibility for cost savings and even more complete datasets in comparison to data from offshore meteorological (met.) masts. Alternative applications are promising as well but not further discussed in this contribution.
To reach bankability of the measurement data from floating LiDAR devices and with it a sustained acceptance in the industry, appropriate (pre-application) testing is indispensable. How to perform the testing and draw the relevant conclusions is to be prescribed in particular guidelines.

Guidelines for application of floating LiDAR systems

At present, we know about two relevant sets of guidelines for the application of floating LiDAR systems that are briefly summarised here.

The *OWA Roadmap* (Carbon Trust Offshore Wind Accelerator roadmap for the commercial acceptance of floating LIDAR technology, CTC819 Version 1.0, Nov. 2013) [1] basically introduced different stages of maturity – Baseline, Pre-commercial, and Commercial – with associated prerequisites as well as recommended fields of application for the systems to be considered. For the pre-commercial stage, for instance, a pilot validation trial is required to have been completed successfully including the independent confirmation of certain acceptance criteria that are also proposed in the document.

A *Recommended Practice for floating LIDAR Systems* is presently compiled as an output of the IEA Wind Annex 32 and to be delivered by summer/autumn 2015. The document comprises guidelines on issues as e.g. system configuration, characterisation, assessment of suitability as well as the design and execution of WRA campaigns on the basis of floating LiDAR technology. The testing considered

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for the Recommended Practice includes initial trials for the assessment of system accuracy, its availability and sensitivity to metocean conditions, as well as pre- (and post-) deployment validations.

Example: Fraunhofer IWES Wind Lidar Buoy

The concept of the Fraunhofer IWES Wind Lidar Buoy was developed within the R&D project 'Offshore Messboje', funded by the German Federal Ministry for the Environment, Natural Conservation and Nuclear Safety (BMU) from 2011 to 2013. The first prototype system (referred to as #1 later in this paper) was completed as part of the project in spring 2013, an updated second prototype (#2) in 2014 – the two systems are shown in Figure 1.
The developed floating LiDAR system integrates a pulsed Windcube v2 or a cw ZephIR 300 LiDAR device – for prototype #1 and #2, respectively – in an adapted marine buoy (type LT81 with the following dimensions: 7.2 m height, 2.55 m diameter, 4.7 t weight). For further specifications we refer to [2]. A motion-correction algorithm developed by Fraunhofer IWES has been implemented as part of the post-processing of the recorded data.

For both prototypes we conducted respective offshore trials – in 2013 and 2014, respectively – to validate the realised concept and prepare the system for the pre-commercial stage according to the OWA Roadmap.

Figure 1
Prototypes #1 and #2 of Fraunhofer IWES Wind LiDAR Buoy – © Photographs: Fraunhofer IWES.

Example: Offshore test(s) next to FINO1 met. mast

The offshore trials were conducted in NW direction in a distance of 450 m to the FINO1 met. mast that is located in the German North Sea about 45 km offshore (See [3] for further details about the FINO infrastructures.) The site features representative offshore conditions: approx. 30 m water depth, yearly-averaged wind speed of 9.9 ms^{-1} at 100 m height, mean wind direction SW, sea currents governed by tides.

The two trials associated to the two prototype systems lasted from 2 Aug. to 6 Oct. 2013 – for #1 – and from 5 Aug. to 30 Sept. 2014 – for #2.

Figure 2 shows the setup and the main results for test #1. For further results we refer to [2]. During the trial, 65 complete days of data were collected. An overall System Availability, defined according to [1], of 98% was determined – Post-Processed Data Availability was less due to missing motion data. A very good correlation between the mean wind speed data of the device under test and the reference met. mast was found even with no motion correction applied.

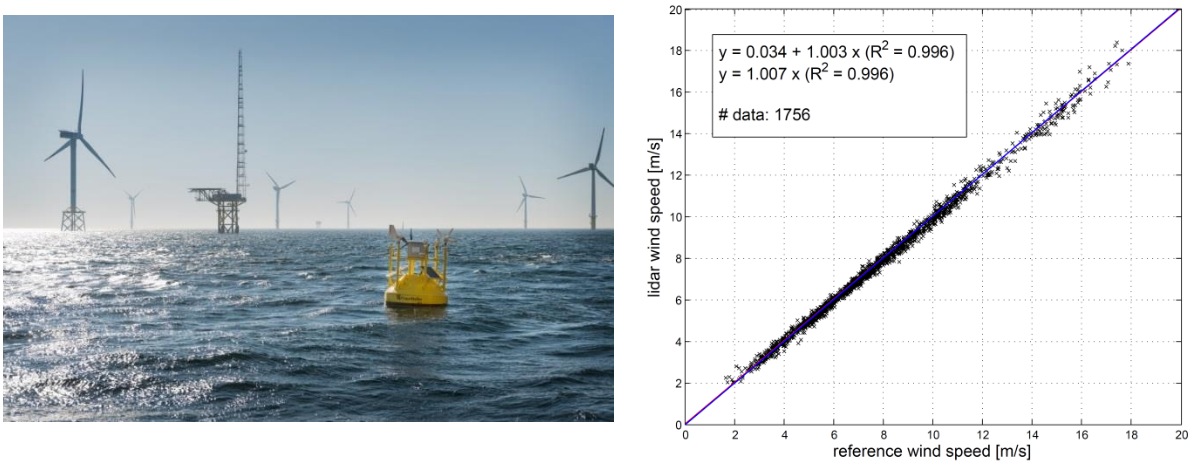

Figure 2 Setup and results of first offshore test (prototype #1) next to FINO1 met. mast used as reference.

As further discussed in [2], the application of motion correction is necessary for the measured wind directions and helpful for the interpretation of Turbulence Intensity (TI) data. For the measured mean wind speeds it leads to a slight further improvement.

For offshore test #2 – this time with the second prototype system integrating a ZephIR LiDAR device – about 30 days of analysable data were collected. System and Post-Processed Data Availability were for this dataset on the same level, i.e. motion correction was applicable to all recorded LiDAR data, but only at about 50%. A reason for this was that the used platform was not optimised for the integrated LiDAR device but was the same as for prototype #1. As a result, for instance, the wind generators were not high enough and thus affected by the LiDAR housing. The system did not generate sufficient power and was turned off remotely in order to protect single system components.
Figure 3 shows the correlation plots for the measured mean wind speeds and directions, filtered with respect to the valid wind direction sectors and with motion correction applied. Both plots show a good correlation with regression results that are within the best-practice criteria proposed in [1].

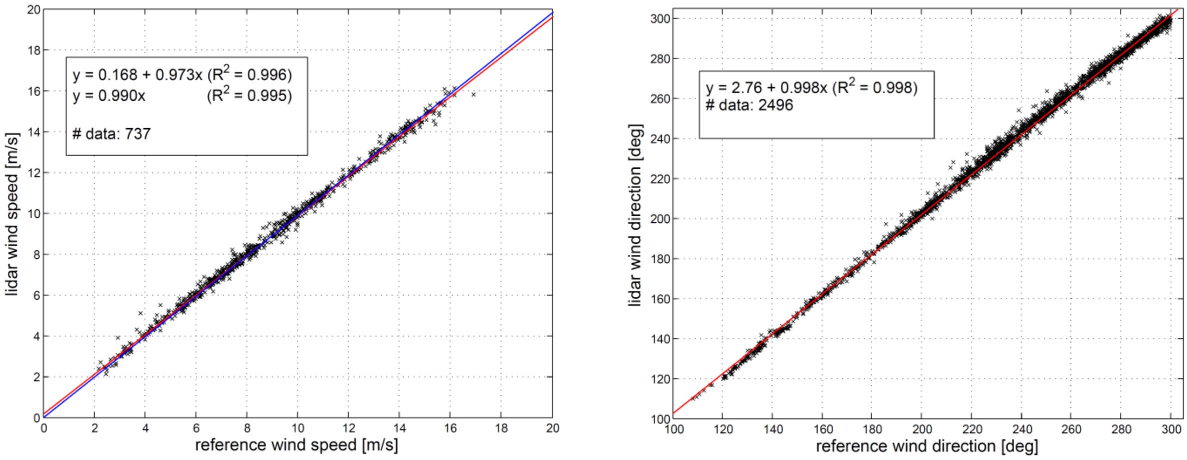

Figure 3 Results for second offshore trial (for prototype #2) next to FINO1 reference mast – for (10-min) mean wind speeds (left) and directions (right).

Conclusions to be drawn from offshore test

Based on the results of an offshore test, the performance of a floating LiDAR system is evaluated in terms of both its availability – with the Key Performance Indicators (KPIs) System and Post-Processed Data Availability as defined in [1] – and its accuracy – with the results of a linear regression analysis as KPIs. Requirements or acceptance criteria for the KPIs, respectively, may vary for different types of tests as e.g. an initial system test, a complete type validation, or pre-/post-deployment tests.

The available sets of guidelines provide a first framework for an evaluation but there are several points that may need further discussion. Exemplary issues and open questions are:

- which acceptance criteria are defined for which kind of test, and which tests are required for the application?
- the specifications for the length of the tests, requirements on the reference (met. mast, or fixed LiDAR device), test site, …
- how to perform data analysis (is a linear regression actually appropriate?)
- deviations to onshore verification test to be considered (distance between device under test and reference, types of reference masts, accessibility of test site, …)

Finding solutions for these open issues may lead to even more reasonable and complete guidelines for testing floating LiDAR systems that – together with the appropriate reference infrastructures – forms a crucial prerequisite for the application of the technology in the offshore wind industry and in particular for WRA campaigns.

References

[1] Carbon Trust Offshore Wind Accelerator roadmap for the commercial acceptance of floating LIDAR technology, CTC819 Version 1.0, Nov. 2013 (available online)

[2] J. Gottschall et al.: Results and Conclusions of a Floating-Lidar Offshore Test. Energy Procedia, Volume 53, pp 156-61, 2014.

[3] http://www.fino-offshore.de/de/