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Robust Low Cost Offshore Power Curve Tests with LiDAR

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Abstract

Testing the power performance of offshore wind turbines is an important part of operating an offshore wind farm. The key impediment to offshore power curve tests so far has been the high cost. Hitherto, it has been necessary to install an expensive offshore met mast to obtain the necessary measurements. The ability to install scanning lidar on the transition piece of an offshore wind turbine provides a valuable opportunity to eliminate the cost of the offshore met tower and make highly cost-effective measurements.

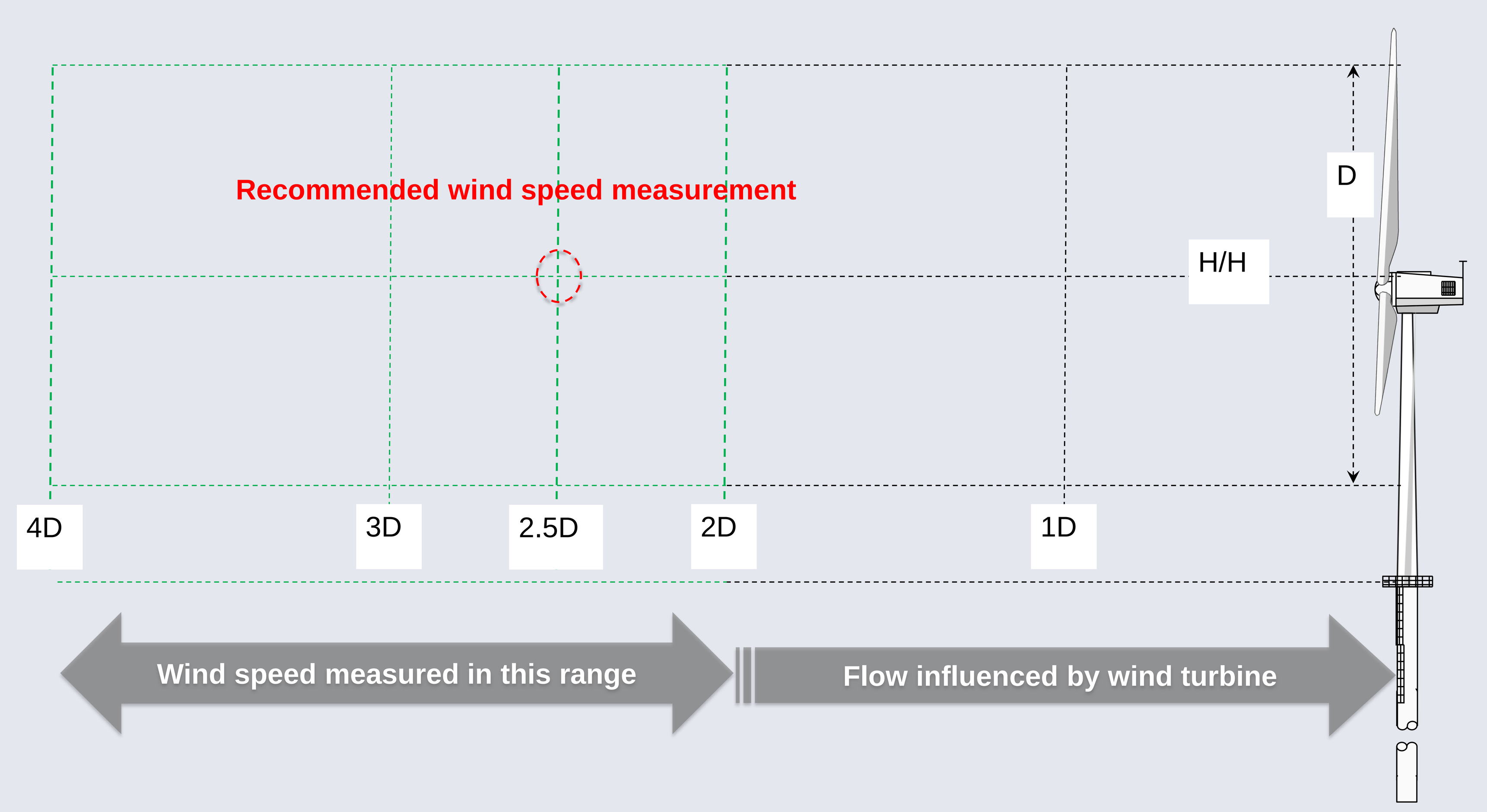
The set up needed to be compliant with the draft 2nd edition of the power curve test standard IEC 61400-12-1. This requires “ground based” lidar methods. Nacelle mounting is not compliant, but mounting on the transition piece satisfies this requirement. A further IEC requirement is measurement at hub height 2.5 rotor diameters upwind of the test turbine.

IEC Requirements

IEC 61400-12-1 2nd edition (draft) [2], Annex L, describes the requirements remote sensing devices must fulfil to be considered for power curve tests. Section L.1 (General) states:

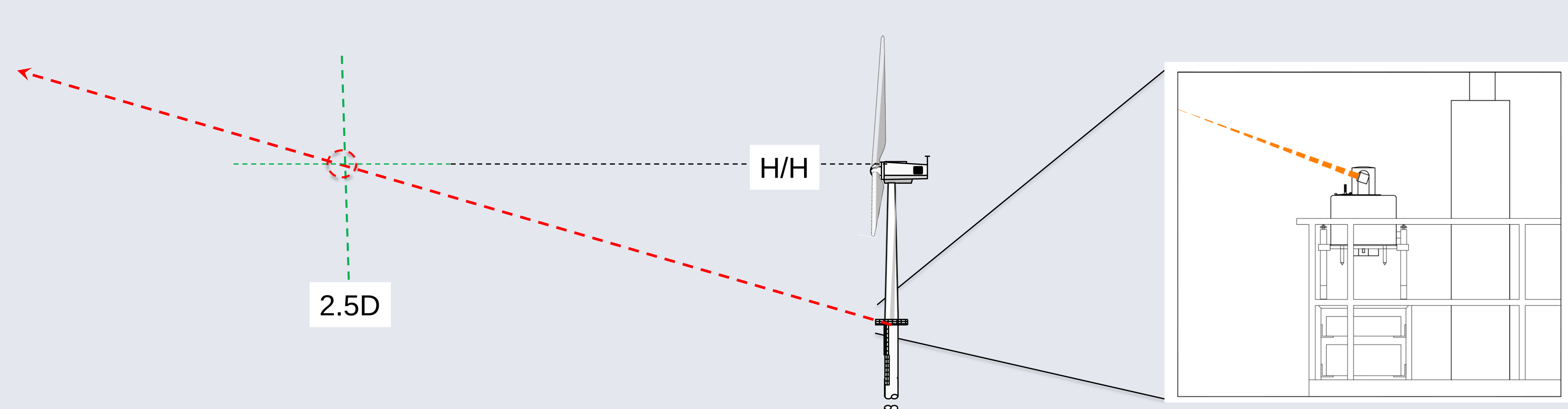
> ***“Only ground based remote sensing devices are used (e.g. nacelle mountings are not included)”***

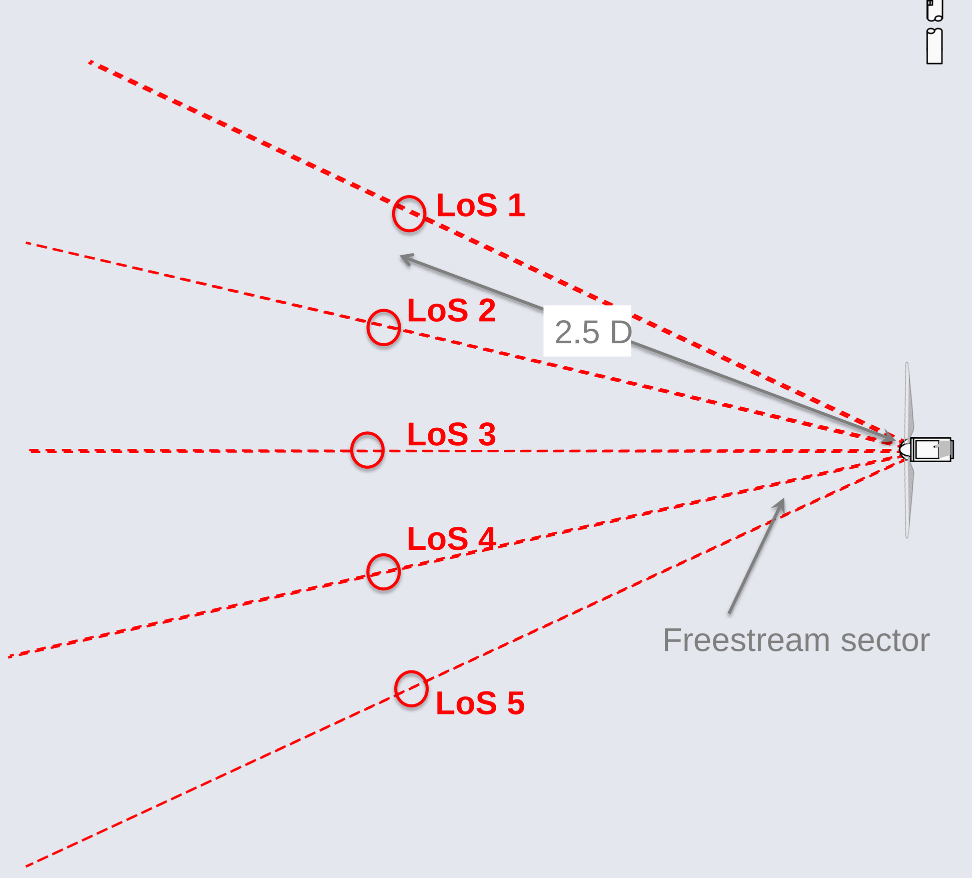
So ***floating and nacelle mounted Lidars are explicitly excluded from the relevant standard***. Power production is compared to wind speed at hub height 2.5 rotor diameters upwind



Measurement set up

The elevation is set to acquire hub height inflow wind speeds 2.5 rotor diameters upwind in the free stream sector





Motivation:

How to achieve maximum IEC compliance possible without incurring the expense of an offshore met mast [3, 4].

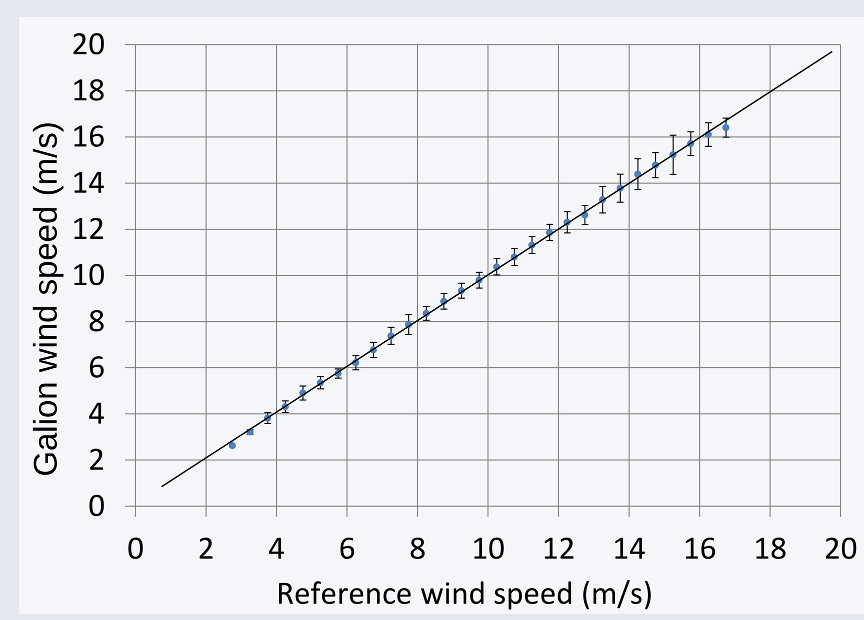
This overcomes cost barrier to enable further de-risking of offshore wind power projects.

The method described here fulfils the requirement for a “ground based method”.

Comparison of different measurement concepts

Bank grade data has been delivered by • Masts • Lidar on platforms and will be delivered by • Lidar on the transition piece	IEC Compliance: Control anemometry available	IEC Compliance: Ground based measurements	Measures conditions across entire rotor disc	Established track record of accepted data	Standard calibration procedure	Indicative cost
Mast	✓	✓	✗	✓	✓	10,000,000
Lidar on fixed platform	✓	✓	✓	✓	✓	5,000,000
Floating lidar	✗	✗	✓	✗	✗	1,000,000
Lidar on nacelle	✗	✗	✗	✗	✗	>100,000
Lidar on transition piece	✗	✓	✓	✓	✓	<100,000

In situ comparison of Galion Lidar and mast



Accuracy is verified against reference cup anemometry both onshore and offshore. Measurements are suitable “where a horizontal distance between the location of the measurement device and its measurements is necessary” and “may be recommended [...] for a power performance assessment offshore with the Galion Lidar installed on the transition piece of the test turbine.” [5]

Deutsche Windguard (DWG) has independently reviewed the procedure [6]

- DWG “Considers the application […] an attractive alternative to other possibilities of testing power curves of offshore wind turbines“.
- "The T-piece method is almost fully consistent to the draft revision of the power curve testing standard [...] The only non-compliance [...] is that no monitoring met mast is applied [...] DWG does not see that as a relevant burden for an application of the T-piece method“.
- "Overall, DWG has high hopes for the T-piece method and is looking forward to perform power curve tests with this procedure”.

Conclusions

The methodology described for installing lidar on the transition piece of an offshore wind turbine complies with the draft 2nd edition of the power curve test standard IEC 61400-12-1 to the fullest extent possible without a met mast.

The results of measurements performed at Alpha Ventus and Sheringham Shoal confirm the suitability of this method.

The measurements showed excellent agreement with reference anemometry, with both correlation coefficient R^2 and regression slope m exceeding 0.98% acceptance criteria.

The cost of the power curve test undertaken using this lidar method is less than 1% of the cost of the equivalent met mast based test.

Verification

Independent validations of the VAD scanning, the remote mast and the long term measurement campaigns have been provided by:

Deutsche WindGuard
Fraunhofer IWES
Risø DTU National Laboratory for Sustainable Energy
KEMA DNV

References

1. IEC 61400-12-1 1stedition, 2005
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3. Clive, P.J.M., Offshore power curves for onshore costs, DEWEK 2012
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5. Gottschall, J., Galion Lidar Performance Verification, Fraunhofer IWES, 2013
6. Albers, A., Review of T-Piece Procedure for Power Curve Tests, Deutsche Windguard, 2014