Nacelle Lidar measurements in complex terrain and its application to power performance testing

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Introduction

Measuring the wind in complex terrain is generally challenging. It requires two met-masts, and only considers wind coming from IEC wind sectors corrected by a site calibration. As established by DNV-GL [1], a turbine-mounted Lidar, well validated in flat terrain [2], can be used as an accurate alternative.

In this poster, we expose how a multi-range pulsed turbine-mounted Lidar can be used for accurate wind speed measurements in complex terrain even in non-IEC sectors. Simultaneous measurements at short and long ranges are used in order to take into account both blocking [4] and terrain effects.

Objectives

The purpose of this poster is to present results obtained in complex terrain where a Wind Iris pulsed turbine-mounted Lidar has been used with a new multi-ranges method. A combination of simultaneous short and long ranges measurements (from 80 to 400 m) is used to determine the turbine blocking effect and improve the Lidar's wind speed accuracy in non-IEC sectors where the terrain effect is significant.

More precisely, the objectives of this poster are to:
- Validate the achieved wind speed accuracy against an IEC compliant met mast with site calibration
- Validate its use for power curves measurements in IEC sectors corresponding to flat terrain
- Apply this method for power curves measurements in all sectors and evaluate how this could beneficially be applied to accelerate power curves measurements in complex terrain

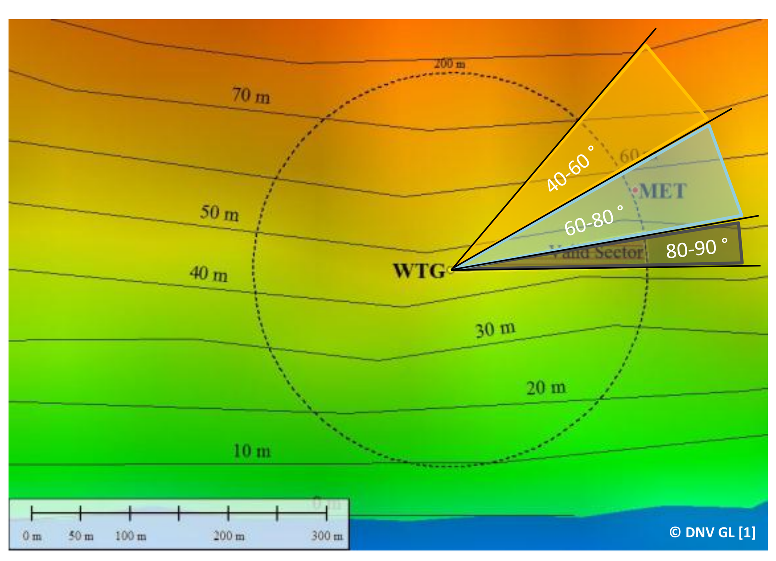
Method

As explained, the method takes advantages of simultaneous short and long ranges measurements. It is decomposed into 3 steps explained below.

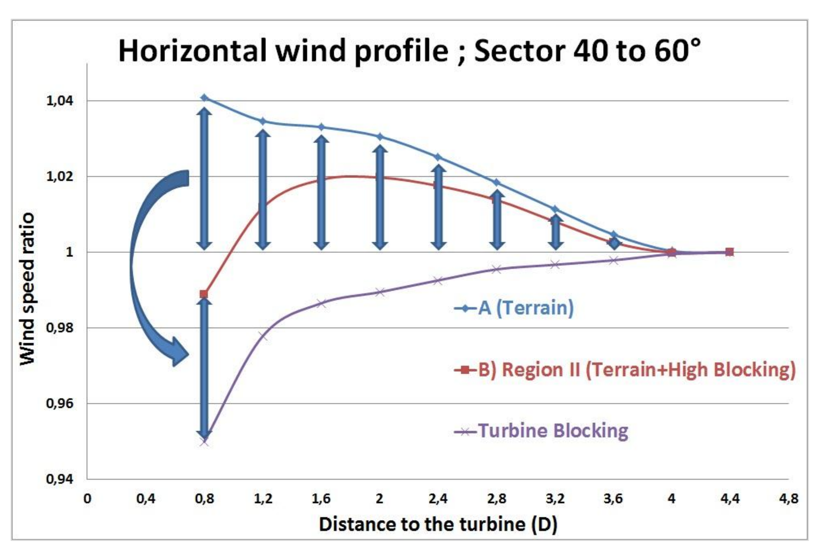
1.Definition of the turbine modes of operation
SCADA data is used to define different turbine operating modes which help define what effects need to be compensated for in the next step of analysis.

Turbine mode	Effects	RPM	Pitch
A. Curtailement	Terrain	0 to 2	-
B. Power curve region II	Terrain + High blockage	9 to 14	< 0
C. Power curve region III	Terrain + Low blockage	> 15	> 0

2.Discrimination of the terrain effect from the blocking effect
In the present site, three wind sectors are defined in the dominant wind direction. In each, turbine modes A, B and C translate into different wind speed evolution toward the turbine due to topography.



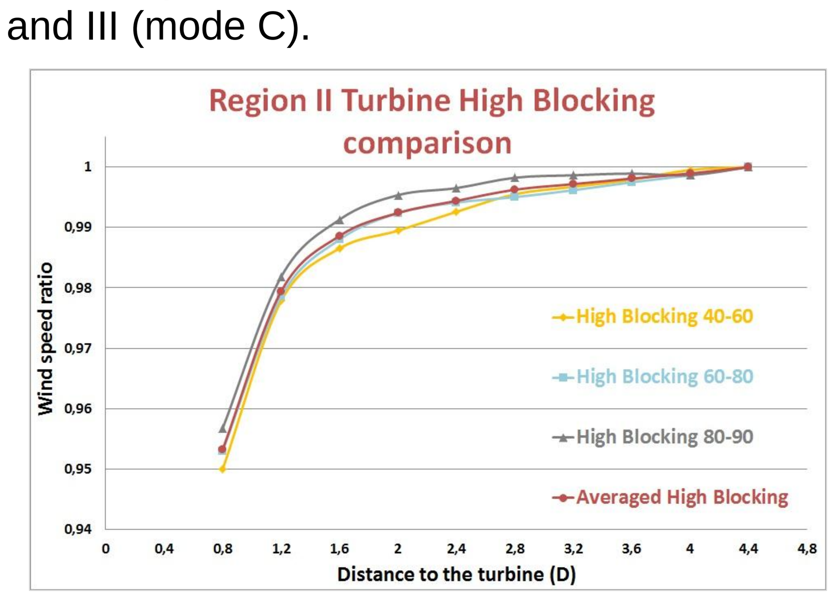
Sector	Slope	Terrain type
40°-60°	11%	Very complex
60°-80°	6,5%	Moderately complex
80°-90°	2%	Flat

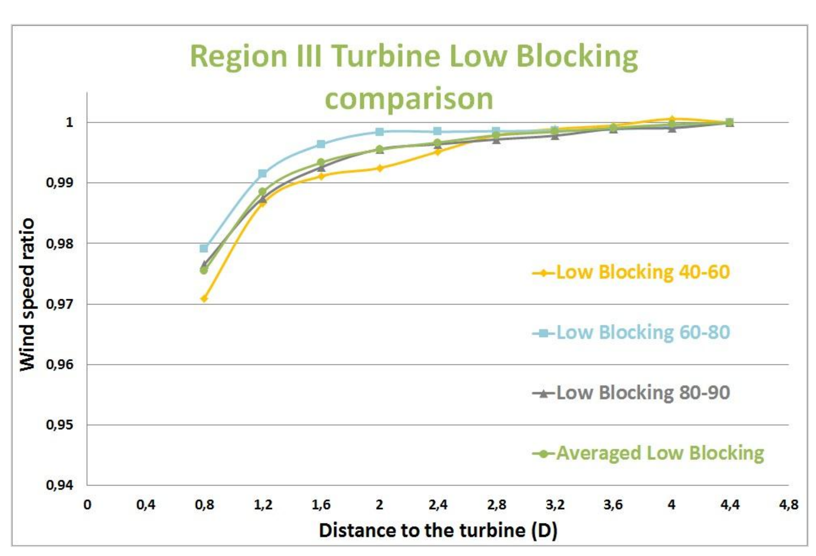


In each sector, the wind speed (red) evolves as a combination of the terrain effect (blue) and the blockage effect when approaching the turbine. The terrain effect can be determined from when the turbine is curtailed (mode A). The flow blockage from the turbine can thus be deduced:

Turbine Blocking = (Terrain + Blocking effect) - Terrain effect

The blockage effect is determined with this method in each wind sector, for power curve regions II (mode B) and III (mode C).



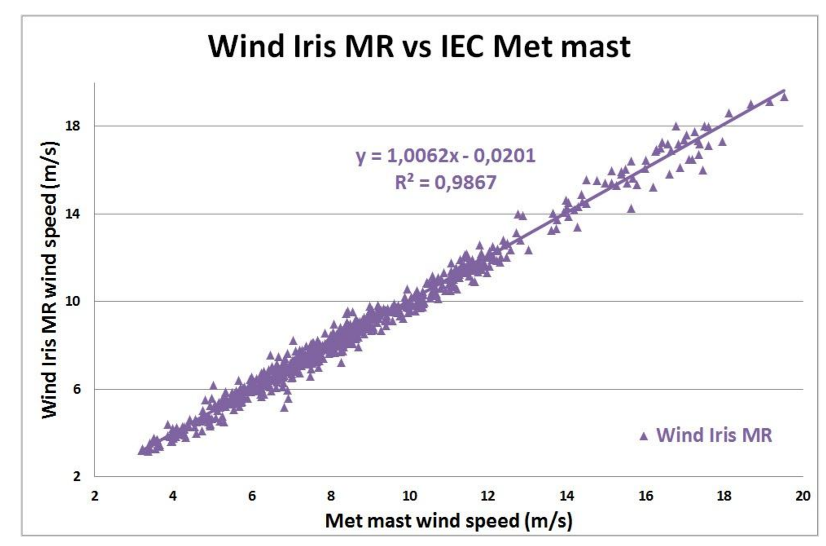


The results show that the blockage (in power curve region II or III) obtained by this method is consistent in different wind sectors with different slope. This demonstrates that blocking and terrain effects are effectively separated and evaluated. One can see the blocking effect at 0.8D is between 3% and 5%, and depends on the turbine operating mode.

3.Use the blocking effect to improve Lidar accuracy
The previous steps are used to build a blocking effect compensation for any Lidar range, which then allows reducing the uncertainty due to the terrain effects. This consists of applying the correct blocking ratio to the appropriate measured range (for instance 0.8D) according to a reference range (generally 2.5D or more). Results of this method are labeled "MR" for multi-ranges.

Results

Validation of wind speed in 80-90° sector (valid IEC sector)
The following graph presents a wind speed comparison from the Wind Iris MR against the Met mast measurement performed in the 80-90° sector.

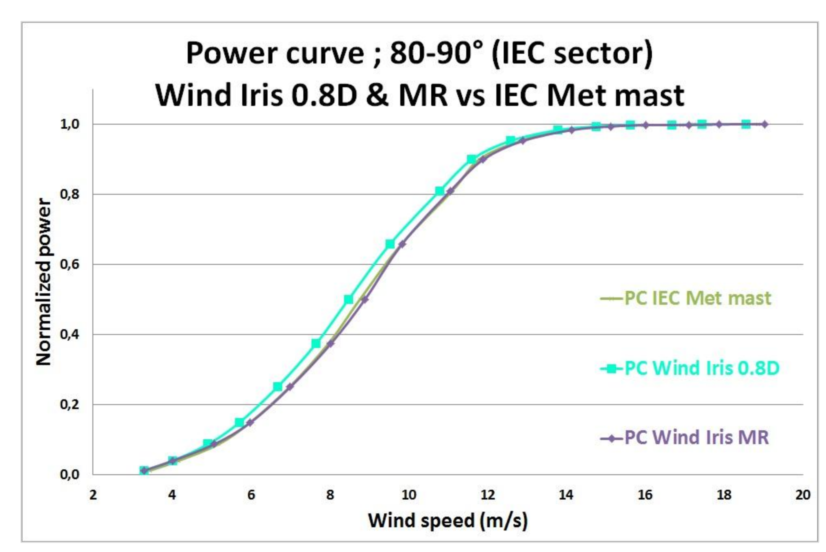


- The MR method is very well correlated with the IEC met mast:

Parameter	Value
Slope	A = 1.006
Bias	B = -0.020
Scatter	R^2= 0.986

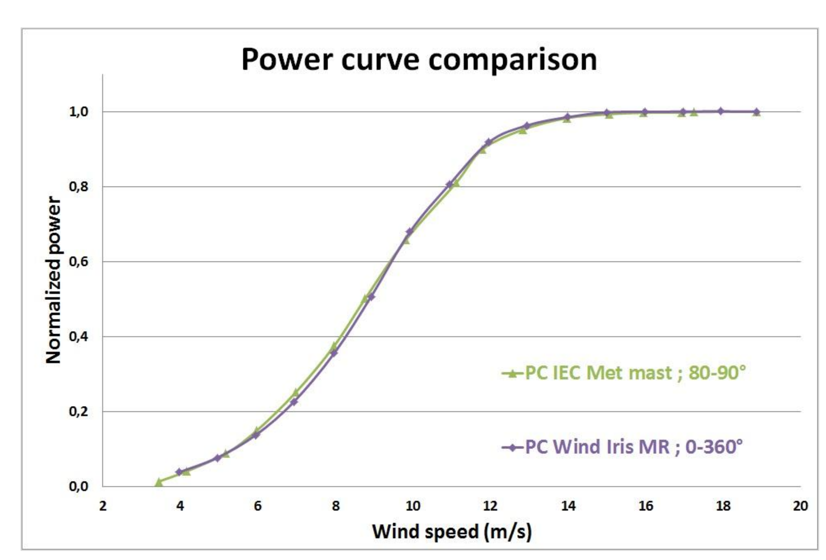
- The scatter remains low, including at high and low wind speeds

Application of the multi-ranges method for power curves measurement in 80-90° sector
The following graph allows to compare three power curves established using the IEC Mast at 200m, the Wind Iris at 0.8D, and the blockage compensated Wind Iris MR, all in the 80-90° sector.



- The multi-ranges method compensates completely the blocking effect.
- The resulting power curve matches perfectly the IEC Met mast power curve.
- Using raw data from 0.8D results in an overestimation of the power curve.
- While only at 0.8D results in a 4% AEP difference with the IEC Met mast (using a 8 m/s Rayleigh distribution) the Multi-Range method results is less than 1% AEP difference against the IEC Met mast

Comparison of power curve measurements using multi-ranges method in all sectors and met-mast in 80-90°
The following graph compares power curve obtained with the Wind Iris MR method applied in all wind sectors (0-360°) to that of the Met mast in the 80-90° sector.



- The Wind Iris multi-range method (MR) and the met mast power curves agree very well.
- The difference in AEP comparison between both power curves is 1%, using a 8 m/s Rayleigh distribution.
- With the use of all wind sectors, the multi-ranges method can result in the reduction of campaign duration by 3 (estimation based on the number of new measurements generated in non-IEC sectors)

Conclusion

- Due to the blocking effect a single measurement closer than 2 Diameters generates a bias in every terrain.
- A method has been developed based on a turbine-mounted Lidar able to simultaneously measure at short and long ranges (up to at least 2.5 Diameter), allowing to compensate for terrain and blocking effects, in every terrain complexity.
- It has been shown that the method can be used in every direction with similar accuracy to an IEC compliant met mast in complex terrain.
- For power curve measurements, applying the method in complex terrain results in shorter campaign with similar results. In this case, campaign duration has been reduced by 3X.
- It is also expected to significantly reduce costs compare to the use of two mast for site calibration
- Similar advantages of MR method can be expected in other applications based on horizontal wind speed such as analysis of nacelle transfer function and wind sector management.
- Further use and validation of this method will be carried out to generate valuable measurements in complex terrain

Acknowledgements

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References

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