WIND POWER | WEATHER & CLIMATE | AVIATION WEATHER | AIR QUALITY & INDUSTRIAL RISK

Metrological validation and operational assessment of 4-beam Wind Iris turbine-mounted Lidar

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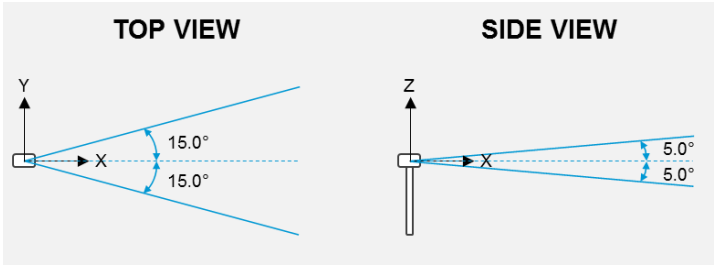
4-beam Wind Iris

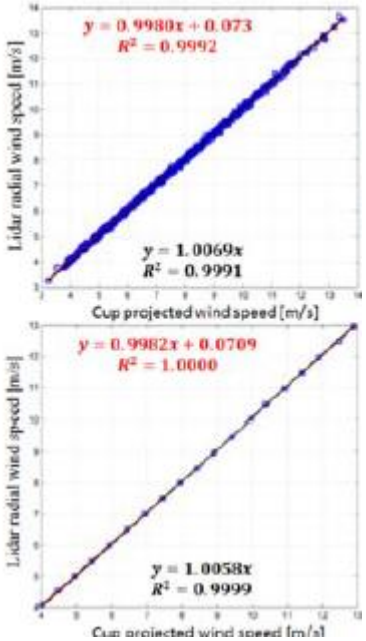
- The 4-beam Wind Iris is the new Leosphere Lidar dedicated to power curve measurement and performance optimization
  - 2 beams are measuring upward and 2 beams measuring downward.
  - The horizontal opening angle is 30°, like the 2-beam Wind iris
  - The vertical opening angle is 10°, for shear measurements
  - Industrialized to be cost, operation and service effective



- Two campaign of 3 months on operational wind farms :
  - USA : Sun Edison and DNV GL. Presented at PCWG 25.03.2015. Paul Lawson, “3D Nacelle Mounted Lidar in Complex Terrain”
  - Europe, France: EDF EN. Simple terrain. **To be presented today!**

4-beam Wind Iris calibration

- In the framework of UniTTe (Uniform Turbine Testing), a procedure for 4-beam Wind Iris calibration has been designed : “White box” type.
- Comparison of radial wind speed measurement with cup anemometer undertaken at RISOE test site showed high agreement.
- Leosphere has also designed along with DTU an in-house calibration based on reference Lidars which is available for windcube and may be extended to wind iris



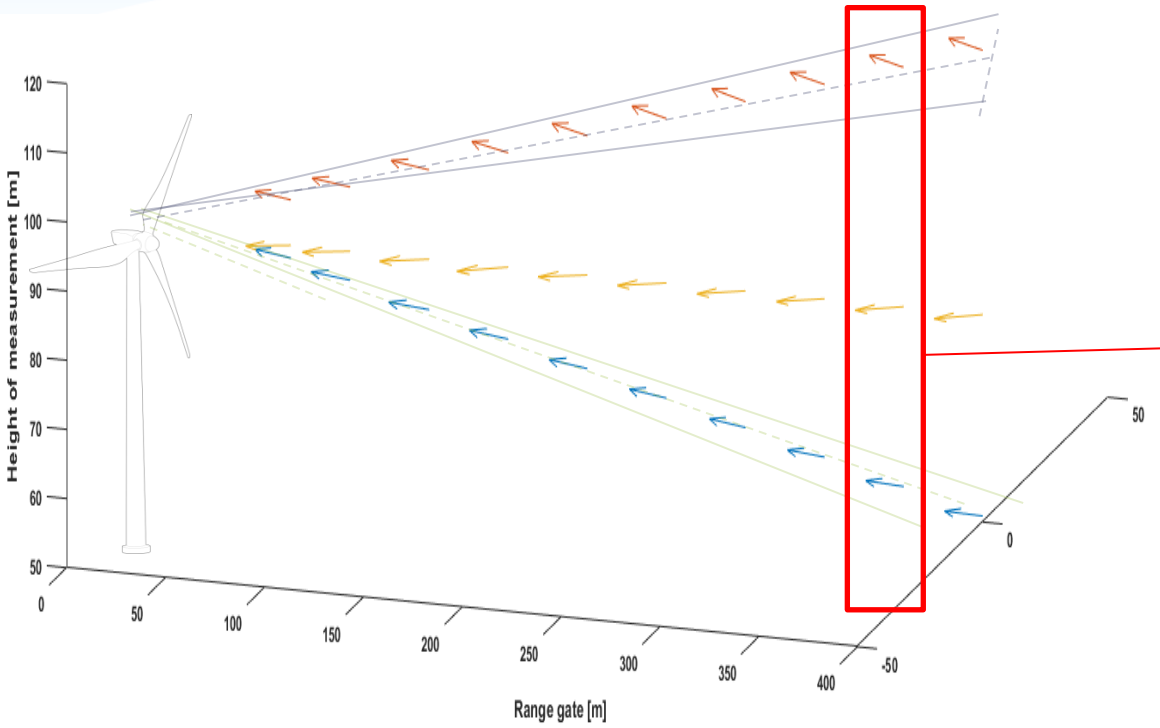
GENERIC CALIBRATION PROCEDURES FOR NACELLE-BASED PROFILING LIDARS; A. Borraccino, M. Courtney, R. Wagner; DEWEK 2015

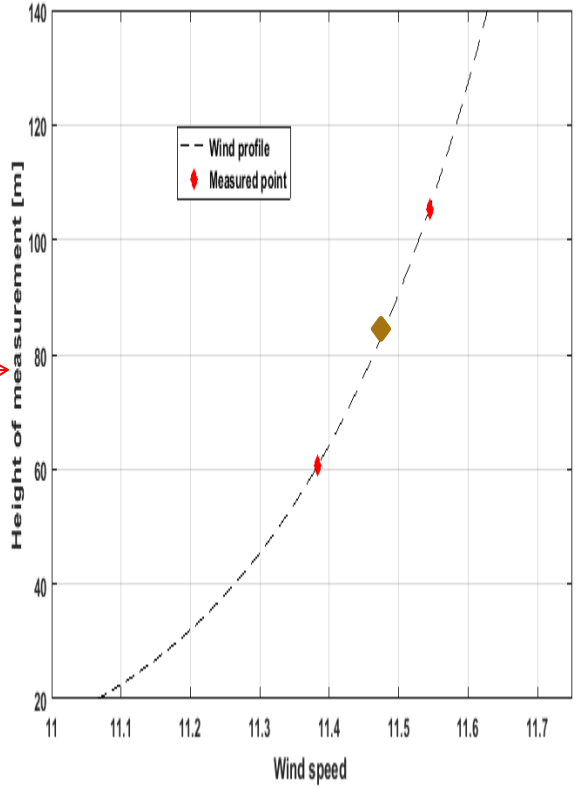
Agenda

1. Description of wind speed reconstruction algorithm
2. Metrology validation of the 4-beam Wind Iris
3. Power performance testing from 4-beam Wind Iris

Description of wind speed reconstruction algorithm

Wind profile is reconstructed





<u>For each of the 10 distance</u> :

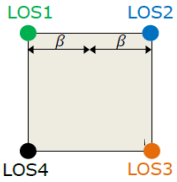
- **Two wind speed are measured at two different heights**
- **The entire wind profile is then extrapolated**

Wind characteristics are measured

From 2 heights of measurement, 4-beam wind iris can retrieve different wind characteristics profiles :

- **Wind speed assuming log profile**
- **Wind direction assuming linear profile**
- **TI assuming log profile**

Range gate	Range gate height difference [m]
#1	8
#2	13
#3	20
#4	27
#5	34
#6	40
#7	47
#8	54
#9	61
#10	67

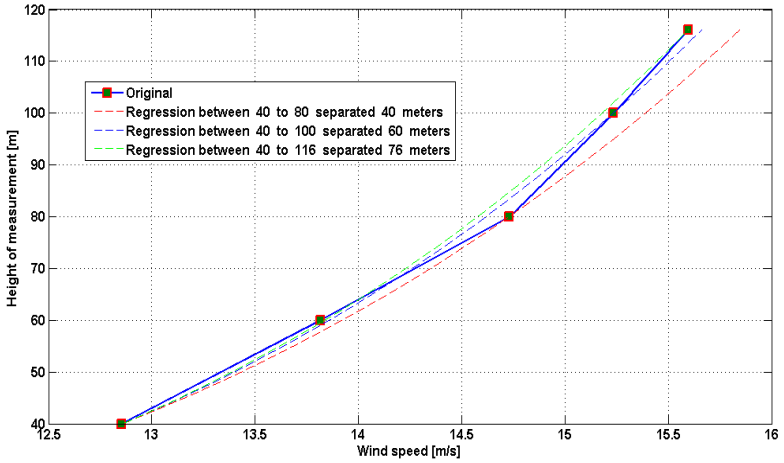


$\beta=5°$

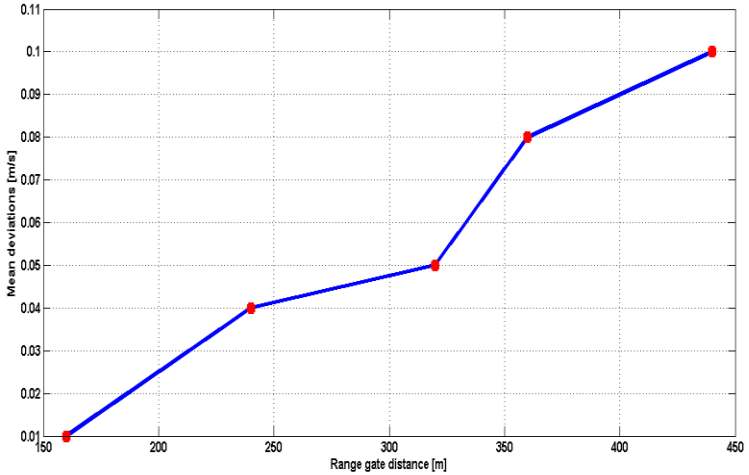
Assumptions have been challenged

Hypothesis

$$\frac{V(Z)}{V(Z0)} = \left(\frac{Z}{Z0}\right)^{\alpha}$$



Reconstruction for a profile

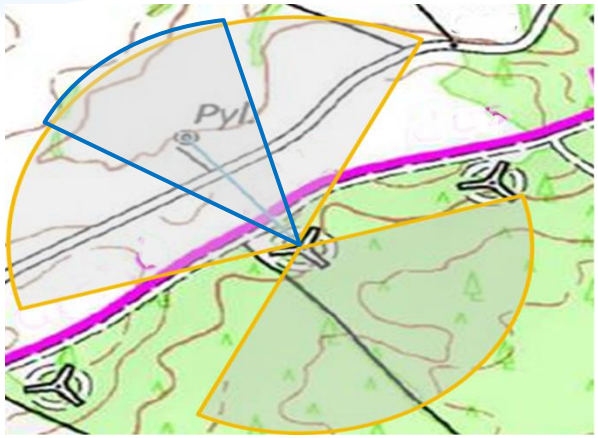


Mean deviation between reconstructed profile and measured wind speed

- Mast measurements were used to compute uncertainties due to log profile assumptions
- **The uncertainty due to log profile assumption lies between 0,01 m/s and 0,08m/s**

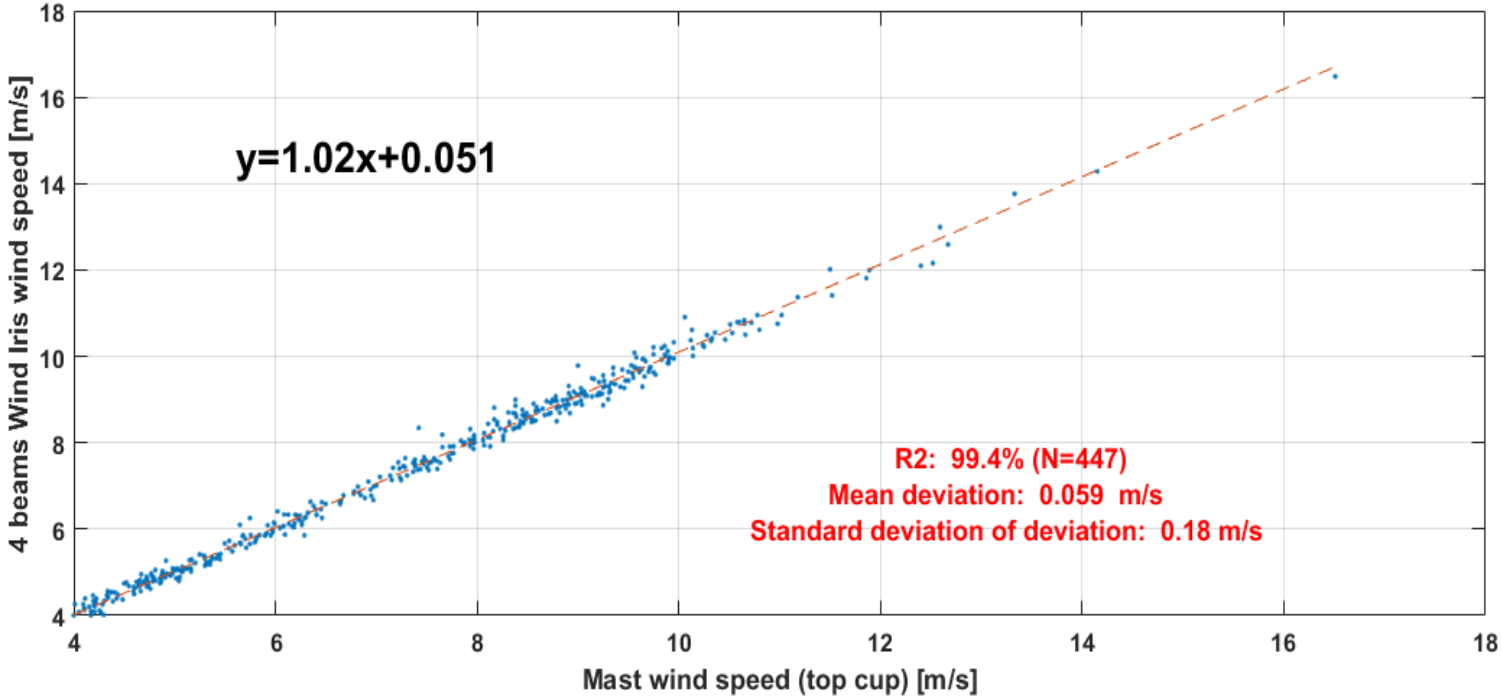
Metrology validation of the 4-beam Wind Iris

A simple terrain site in southern France



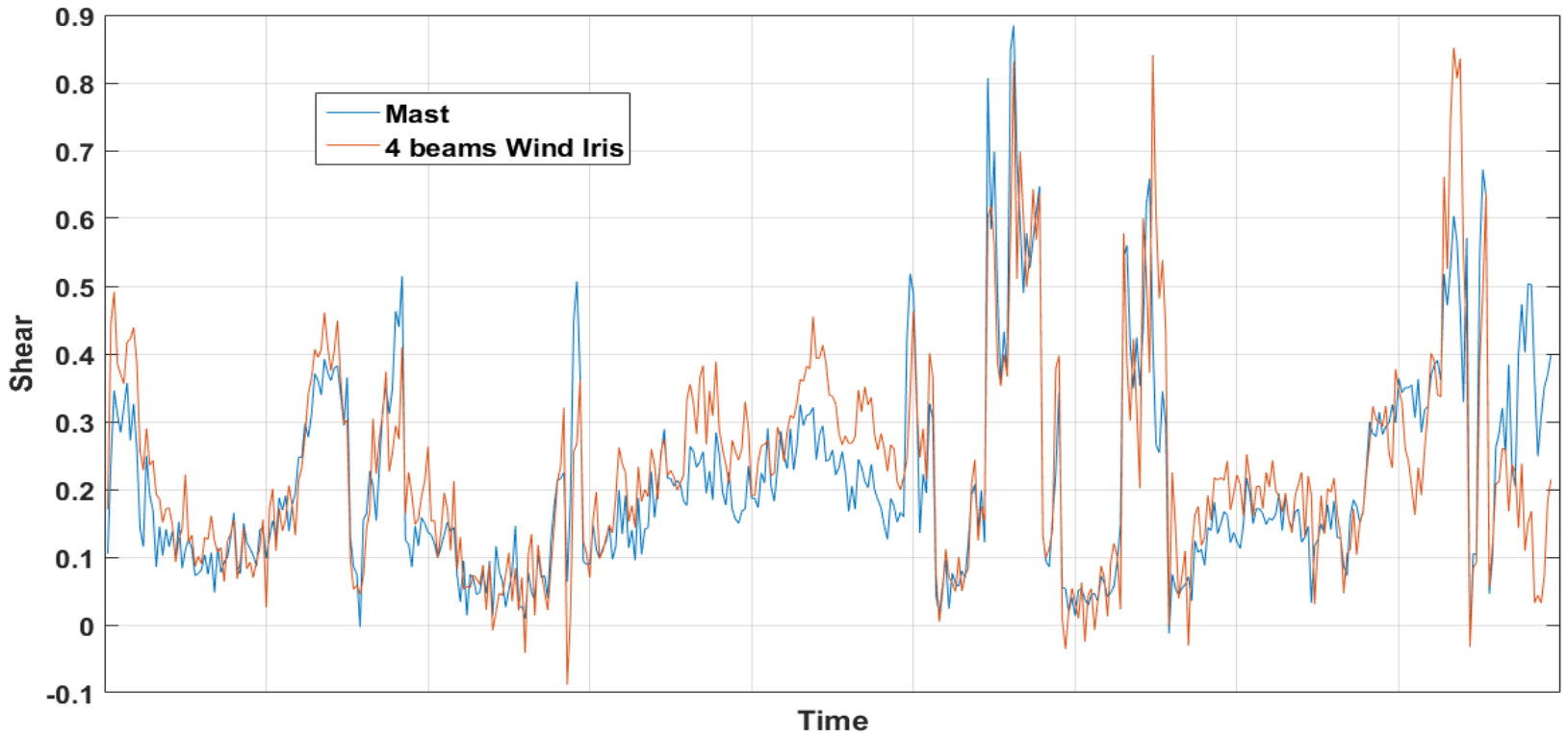
Turbine	• **Turbine 3MW,** operated by EDF EN Services • Hub-height: 80 meters • Rotor size: 90 meters
IEC mast	• Top cup at hub-height • **240 meters** (2.7D) from turbine • **Free wind sector: [315°;335°]** • **Temperature above 0.1°**

Wind speed : equivalent accuracy than 2-beam Wind Iris



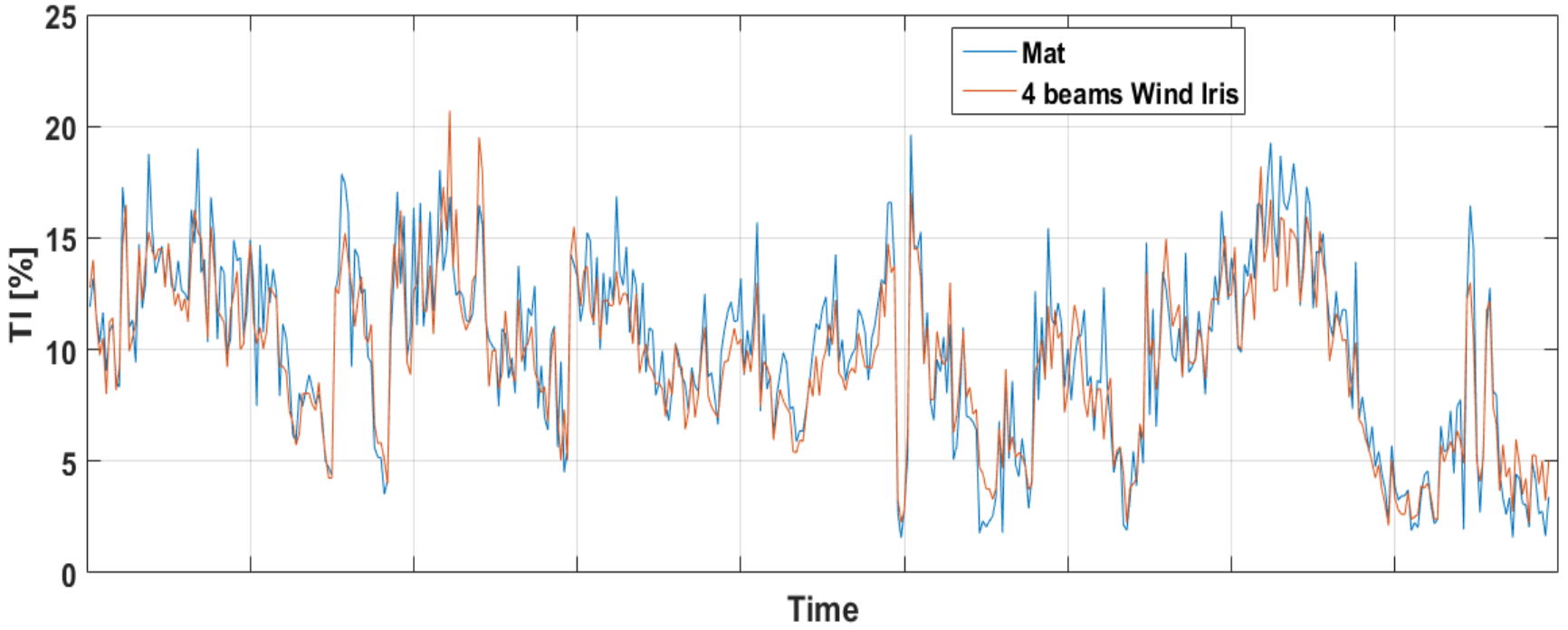
- ***Horizontal wind speed measurement is observed to achieves high accuracy and precision***
- ***No specific trends is observed (wind speed, wind direction,…)***

Shear measurement compared with mast



- ***Shear measured by 4-beam Wind Iris is observed to match most of the time the mast measurements.***
- ***Some difference appears : due to difference in measurement heights?***

Turbulence intensity compared with mast

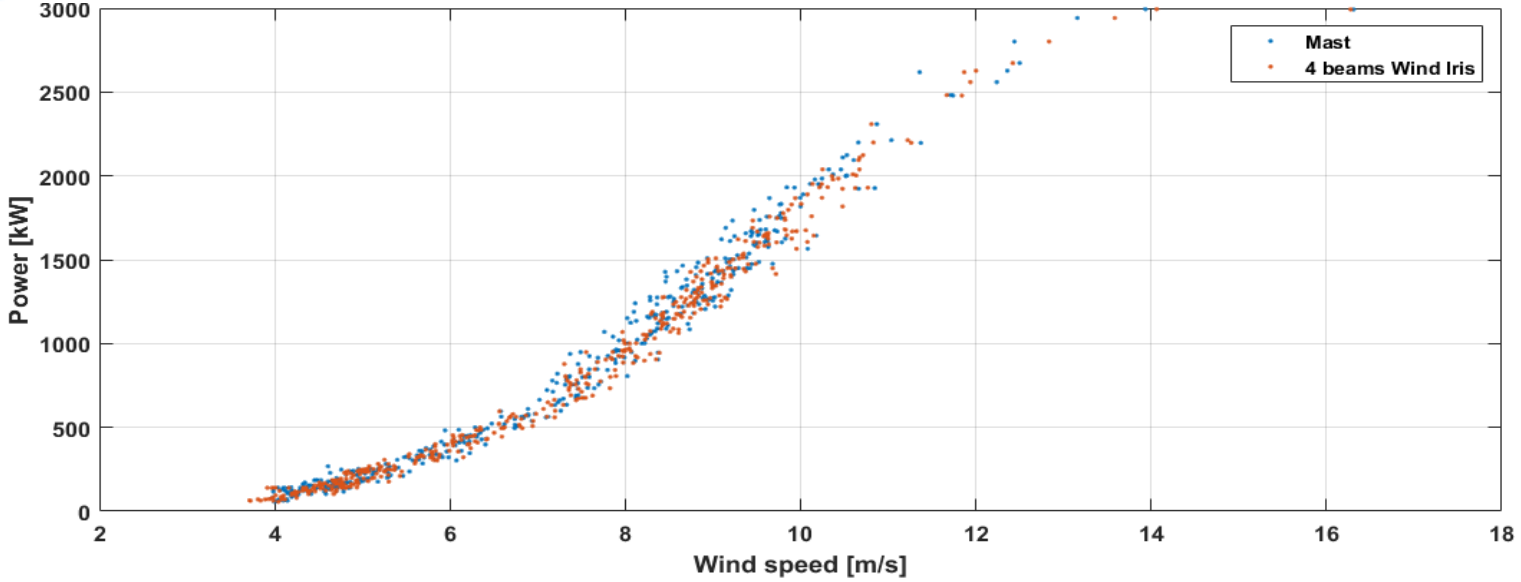


- ***Turbulence intensity measured by 4-beam Wind Iris is observed to match most of the time the mast measurements.***
- ***Some difference appears : linked to atmosphere stability?***

Metrology of 4-beam Wind Iris in simple terrain

	Accuracy	Precision
Horizontal Wind speed	0.06 m/s	0.18 m/s
Vertical wind shear	0.014	0.092
Turbulence Intensity	-0.4 % (absolute)	1.5 % (absolute)

Validating 4-beam Wind Iris from power curve measurement

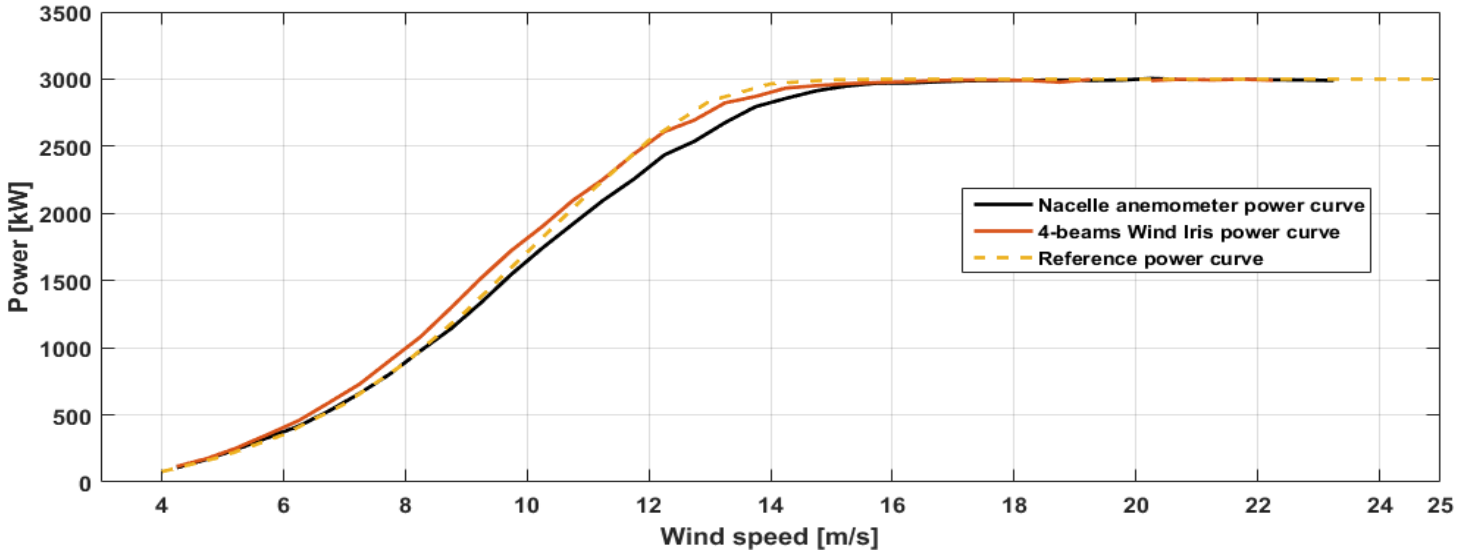


- Power curve following **applicable to Lidar IEC61400-12-1 (ed.1) requirements** (reduced wind sectors, temperature correction,…) is plotted with 4-beam Wind Iris measurements.
- Mast based power curve is plotted on exactly the same time basis so that devices are compared on same wind conditions.
- Mean observed dispersion per bin is 81 kW for 4-beam Wind Iris and 111 kW for mast.
- 4-beam Wind Iris is observed to deliver a less scattered power curve than mast.

Power performance testing from 4-beam Wind Iris

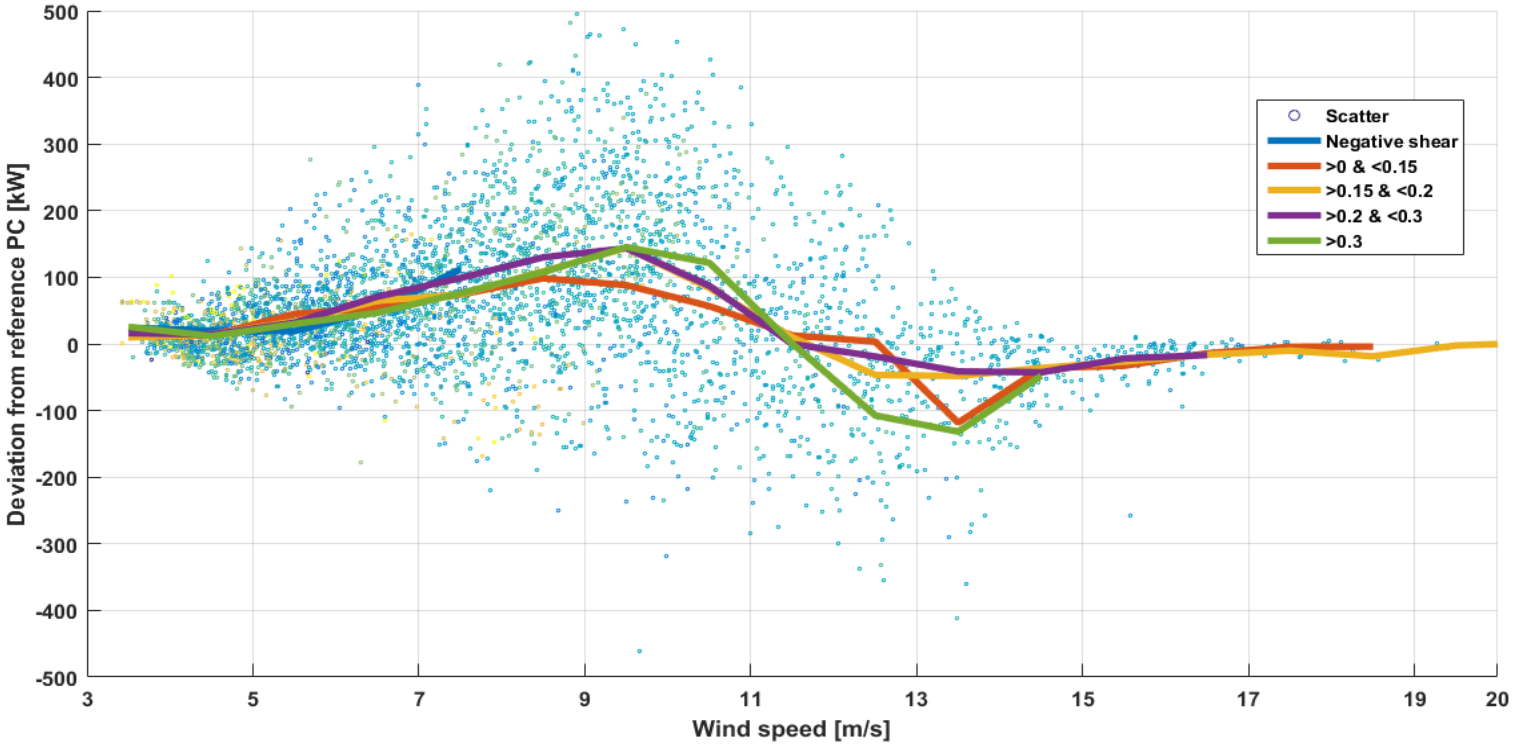
Power performance analysis

Power curve are plotted following adapted requirements established within the EUDP project *(Procedure for wind turbine power performance measurement with a two-beam nacelle lidar, Rozenn Wagner, Rebeca L Rivera, Ioannis Antoniou, Samuel Davoust, Troels F Pedersen, Mike Courtney, Ba-bak Diznabi , 2013)*



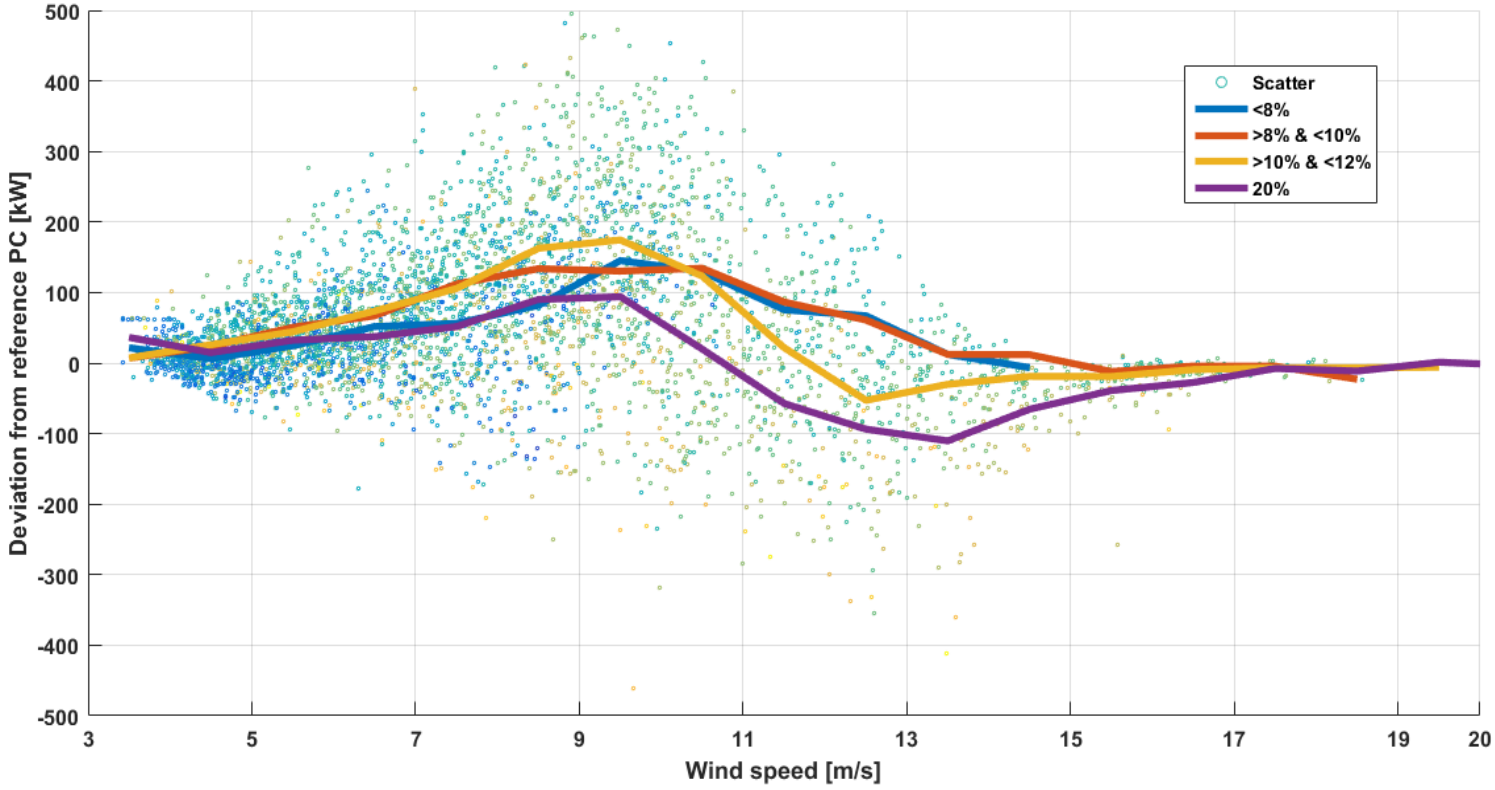
- The nacelle anemometer based power curve **is significantly under the reference power curve apparently** showing underperformances of the turbine.
- The 4-beam Wind Iris based power curve **is in high agreement** with the reference power curve -> There is **no underperformances**. Nacelle anemometer wind measurement is biased (4% overestimation of the nacelle transfer function).

Shear effect on power performance



The higher the shear the more the performances deviates from reference (either underperforming or outperforming)

Turbulence intensity effect on PP



The higher the TI the lower the performance of the turbine is.

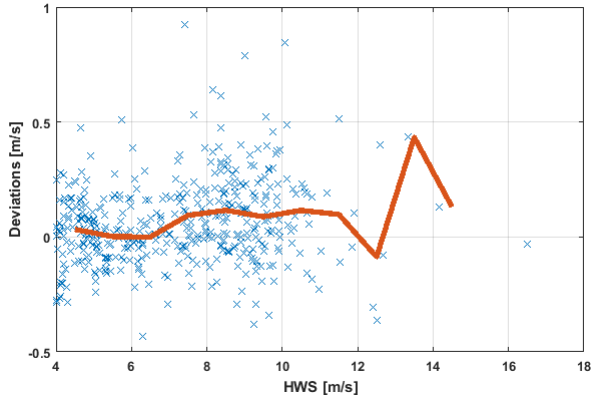
Conclusion

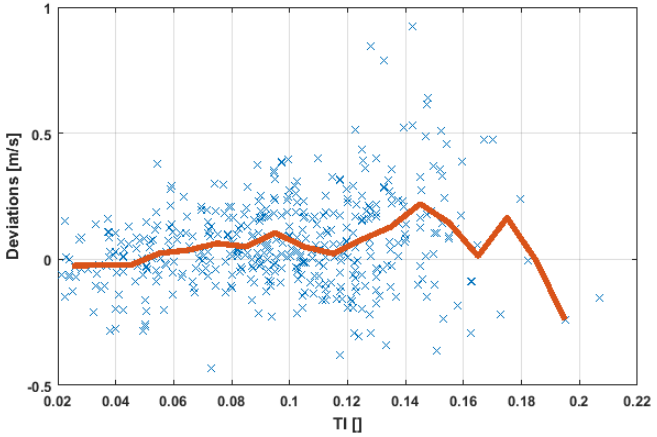
Conclusion

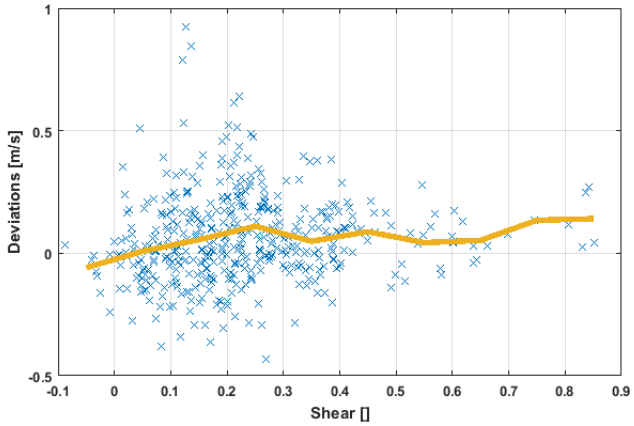
- Metrological performances of the new system are observed to be in the continuity of the well established 2-beam Wind Iris.
- 4-beam Wind Iris permits to measure shear and turbulence intensity with good accuracy and precision although there are deviations, which can be explained by the difference in measurement heights.
- 4-beam Wind Iris will permit to improve the understanding of wind turbine performance in outer range conditions.

Annexe

Horizontal wind speed deviations plotted with mast measurement







Wind characteristic	Impact on deviations
Wind speed	No impact
Wind shear	No impact
Turbulence	No impact

4-beam Wind Iris vs. 5-beam Demonstrator

- The 4-beam Wind Iris is the **new Leosphere Lidar dedicated to power curve measurement and performance optimization**
- 2 beams are measuring upward and 2 beams measuring downward.
- The **horizontal opening angle is 30°, like the 2-beam Wind iris**
- The **vertical opening angle is 10°, for shear measurements**
- Industrialized to be cost, operation and service effective

- The 5-beam Demonstrator is a **R&D Lidar dedicated to Turbine Control projects**.
- Horizontal and vertical optical angles are around 21.4°.
- System (including number of beams and opening angles) can be customized for specific TC projects