Post-processing of operational data to study Power losses due to Wake interactions

Jose Avalez's Master Thesis 2020

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Source: [1]

1. Introduction
General Topic

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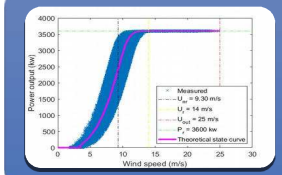
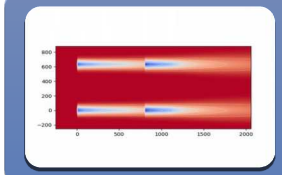
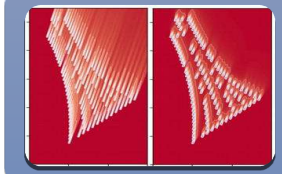
Assessment of wind power production in an offshore wind farm.



Two years of operational data will be analyzed.



Results will be compared against the predictions provided by FLORIS.



The sensitivity of the results to the wind turbine wake model will be investigated.

4. Generalities
Anholt Offshore Wind Farm

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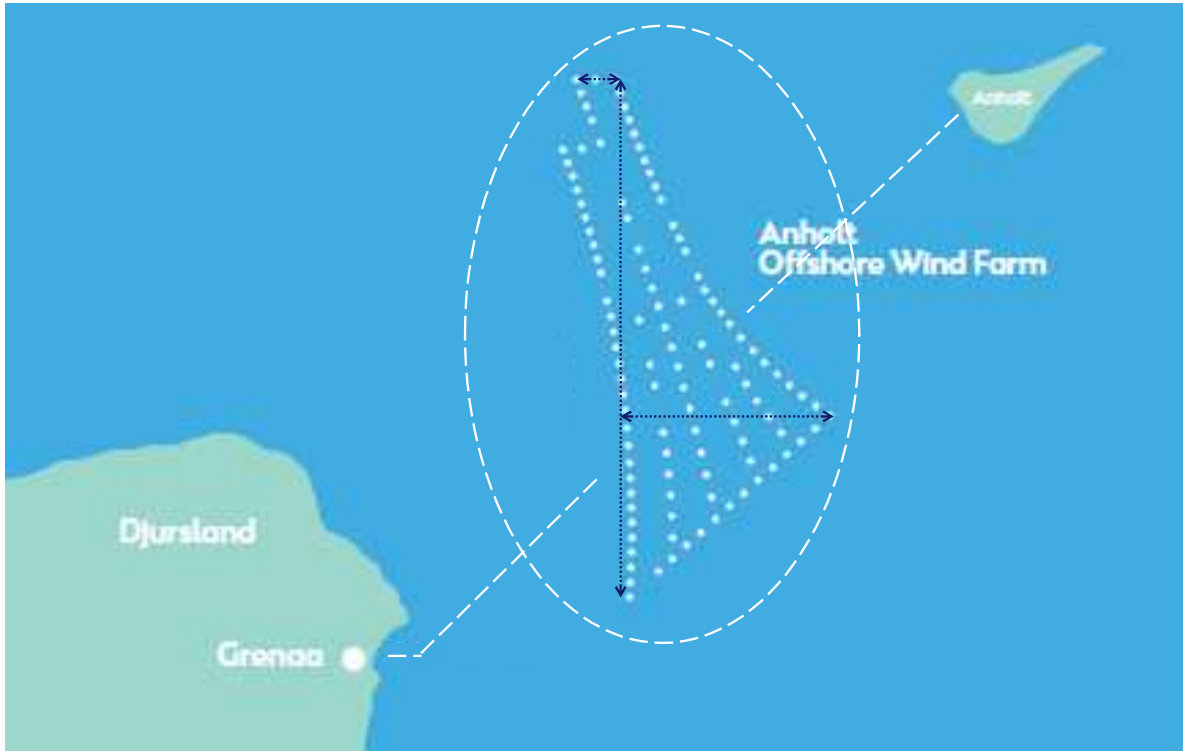
- One of Denmark’s largest offshore wind farms
- Developed by Ørsted in 2011
- 400 MW of installed capacity
- 111 wind turbines
- 20 km length
- 4 km to 12 km width
- 15 km to the shore
- 20 km to Anholt island



Source: [4]

4. Generalities

Turbine model Siemens SWT-3.6-120

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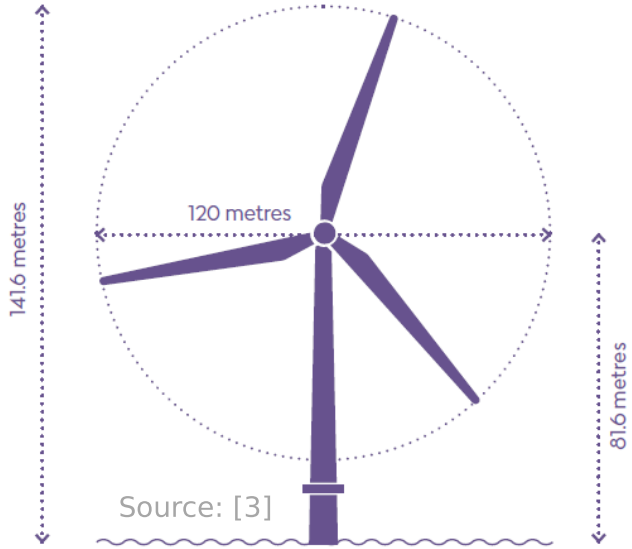
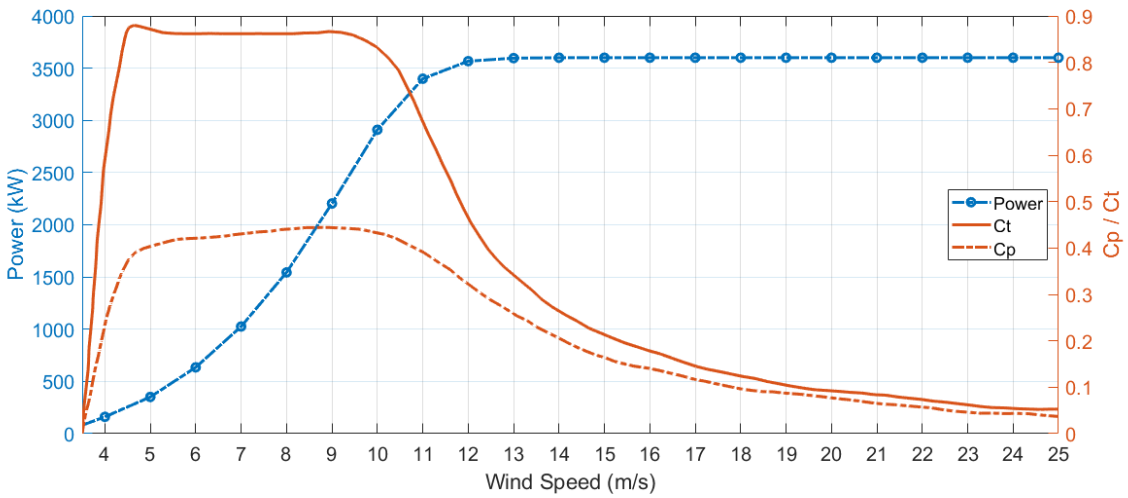
Rated power	3,600 kW
Power control	Pitch
Rotor Tilt	6°
Blade length	58.5 m





Minimum rotor speed	5 rpm
Maximum rotor speed	13 rpm
Cut-in wind speed	3.5 m/s
Rated wind speed	14 m/s
Cut-out wind speed	25 m/s

4. Generalities
Data package

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Location for all turbines

ID
WT number
X coordinate
Y coordinate
Longitude
Latitude

Two years of 10-minute SCADA Data

Wind speed	m/s
Yaw position	deg
Pitch angle	deg
Rotor speed	rpm
Active power	kW
Ambient temperature	C°
Time in operation	sec

1 January 2013 - 30 June 2015

Statistics from ground-based LIDAR

Horizontal wind speed	m/s
Vertical wind speed	m/s
Data availability	%
Height of measurement	m
Active power	kW
Ambient temperature	C°
Time in operation	sec

1 January 2013 - 31 December 2014

- Variables are provided at 10 different heights: 65.6, 85.6, 101.6, 141.6, 185.6, 225.6, 275.6, and 315.6 m.
- The exact location of the LIDAR system and its model is not available.

5. Data Preparation
Wind resource comparison

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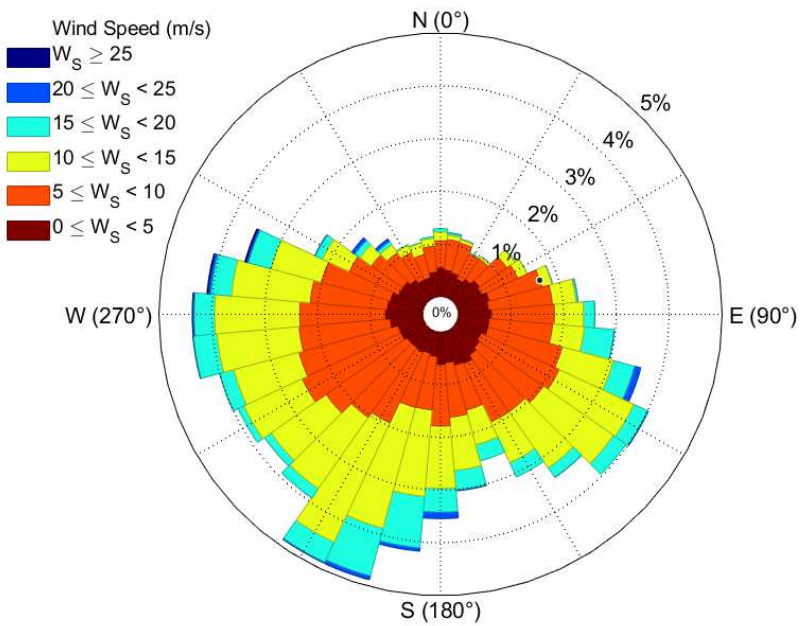
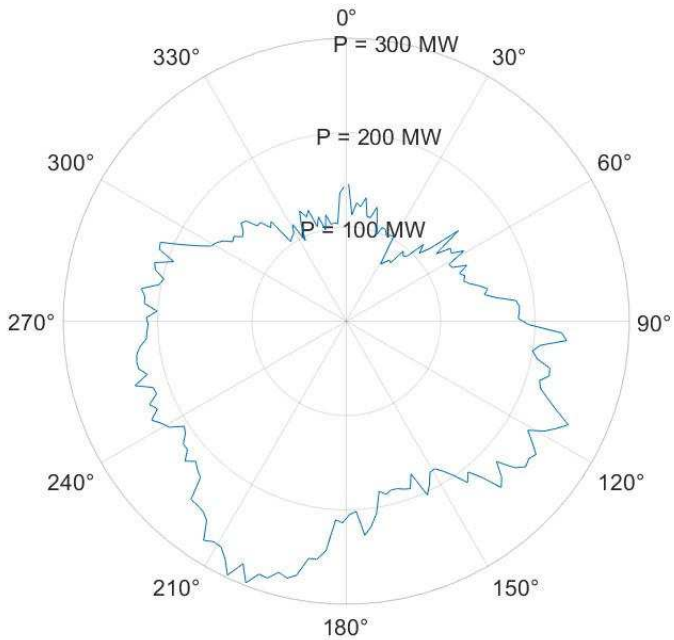
LIDAR, Raw data



Avg power production (based on LIDAR)



5. Data Preparation
Annual energy production

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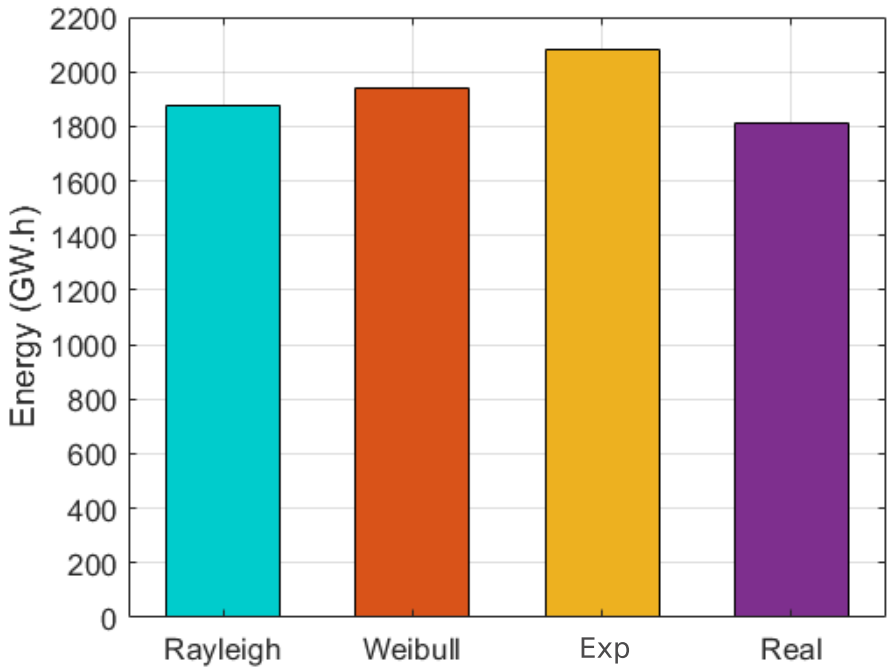
- From 78,667 10-min observations
- Underestimation due to wake losses compared to experimental data

	Rayleigh	Weibull	Exp	Real
Energy (GW.h)	1,878.50	1,937.79	2,83.51	1,809.60
Diff w.r.t. Exp prod (%)	-10.9	-7.5	--	-15.1



5. Data Preparation

Inflow conditions estimation

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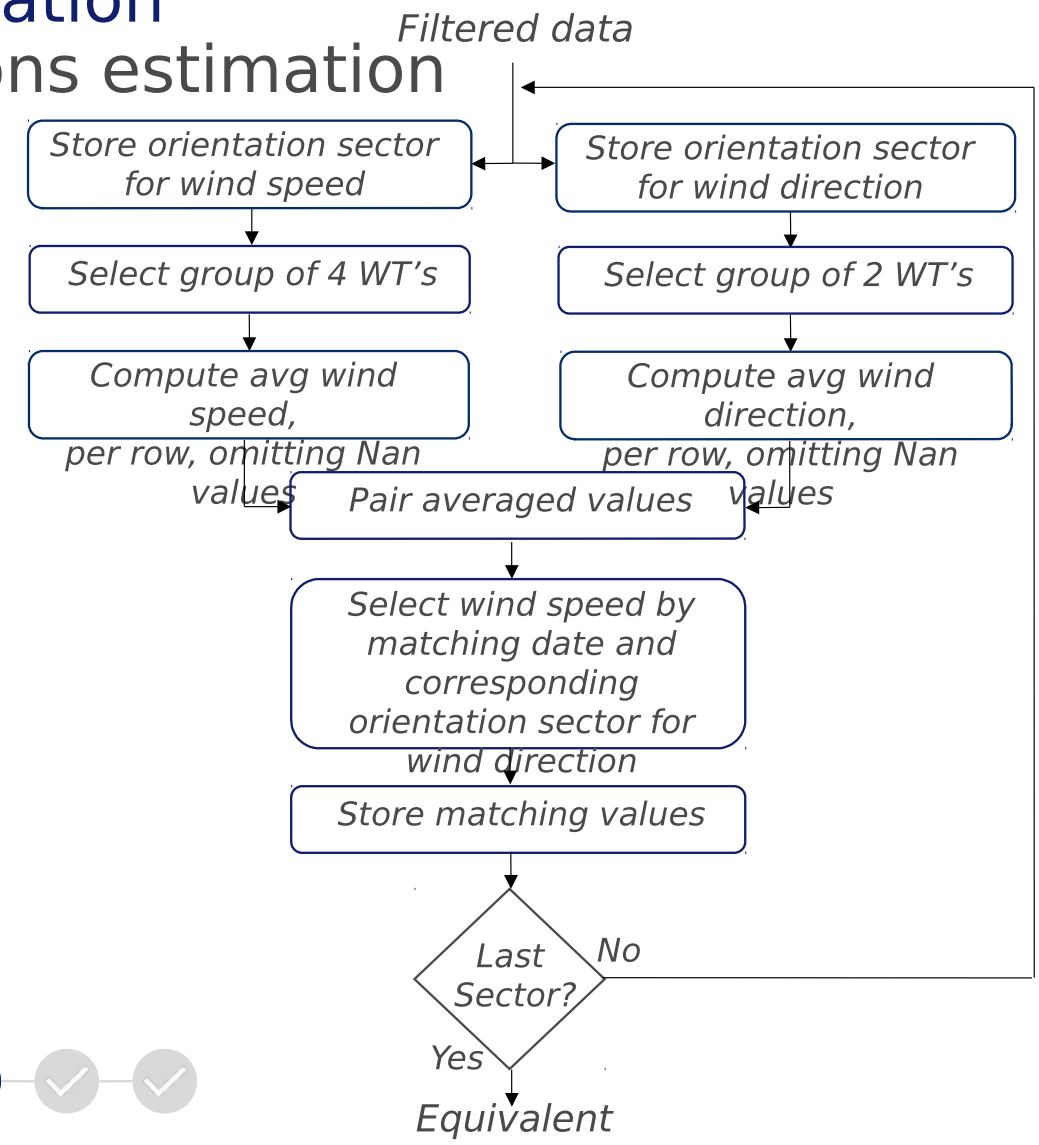
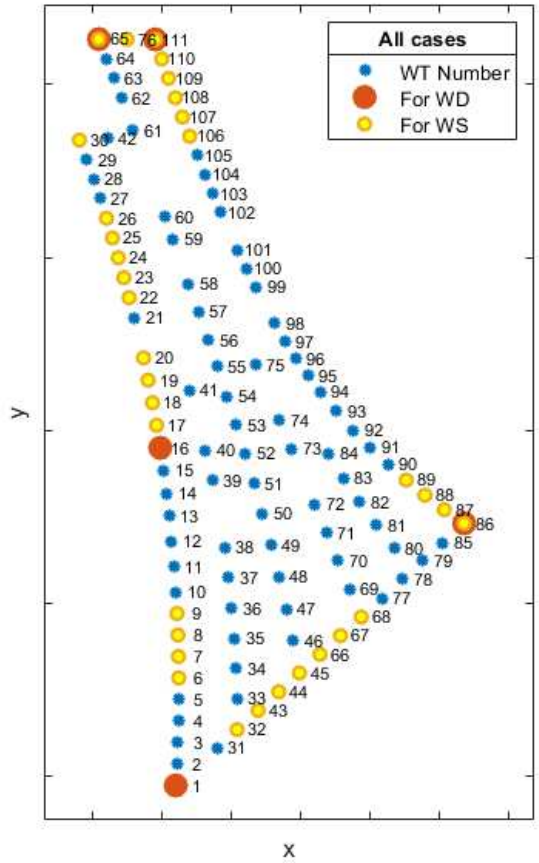
1. Based on Peña et al. 2018 [3]
2. To get inflow wind speeds
3. Estimating average equivalent wind speeds from groups of ***undisturbed*** WT's
4. And avoid the influence of Djursland and the island of Anholt.

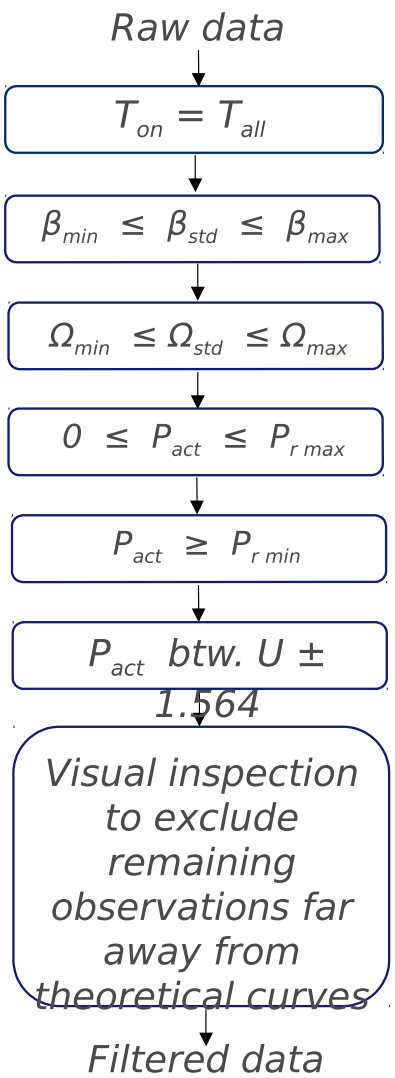


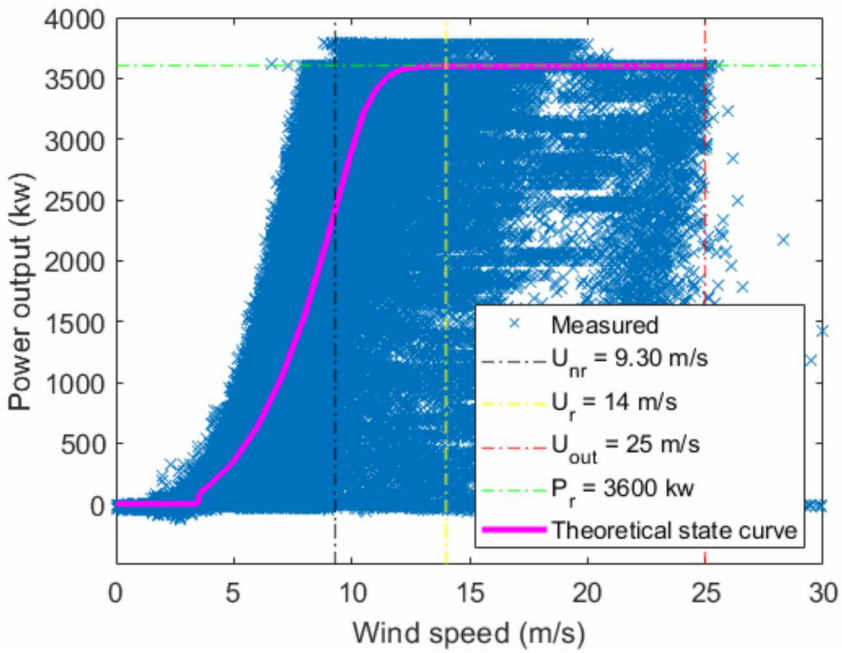


5. Data Preparation

Filtering process

1. Grid connected during entire 10 min period (600 s)
2. Pitch angle std dev btw min and max boxplot values
3. Rotor speed std dev btw min and max boxplot values
4. Power boosting up 1% above Pr
   Power curtailment up to 1% below Pr
5. Power curve trimming and rotor/pitch signal outliers





6. Results
Power production by filtering step

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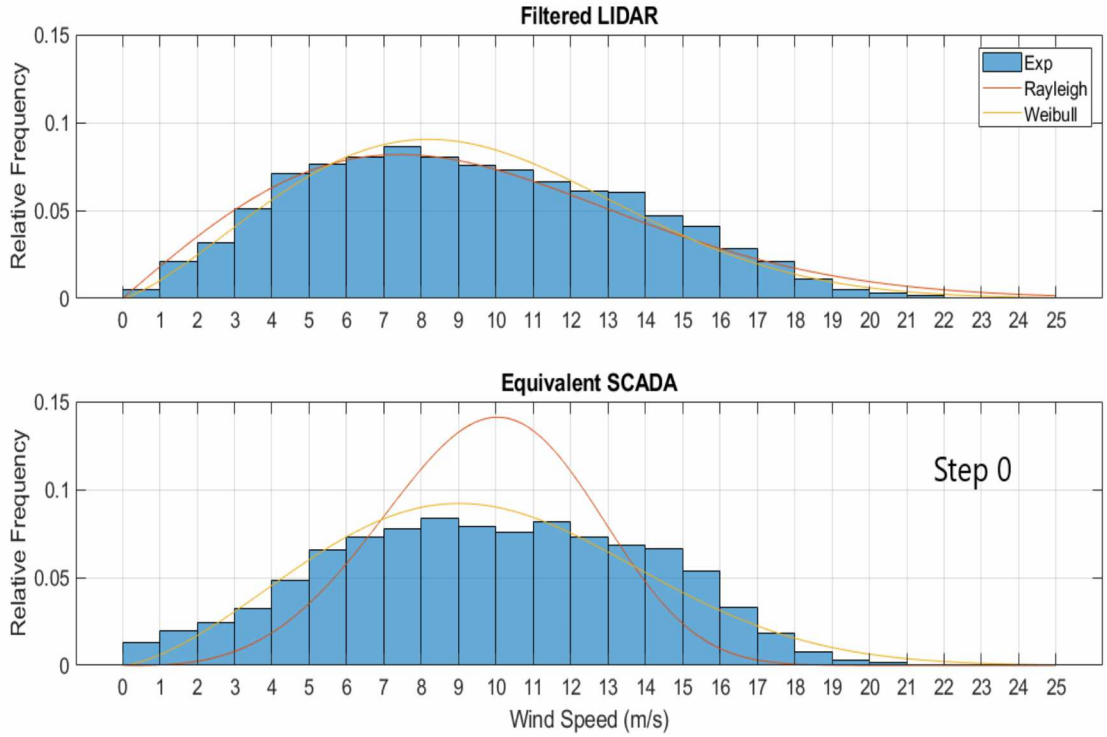

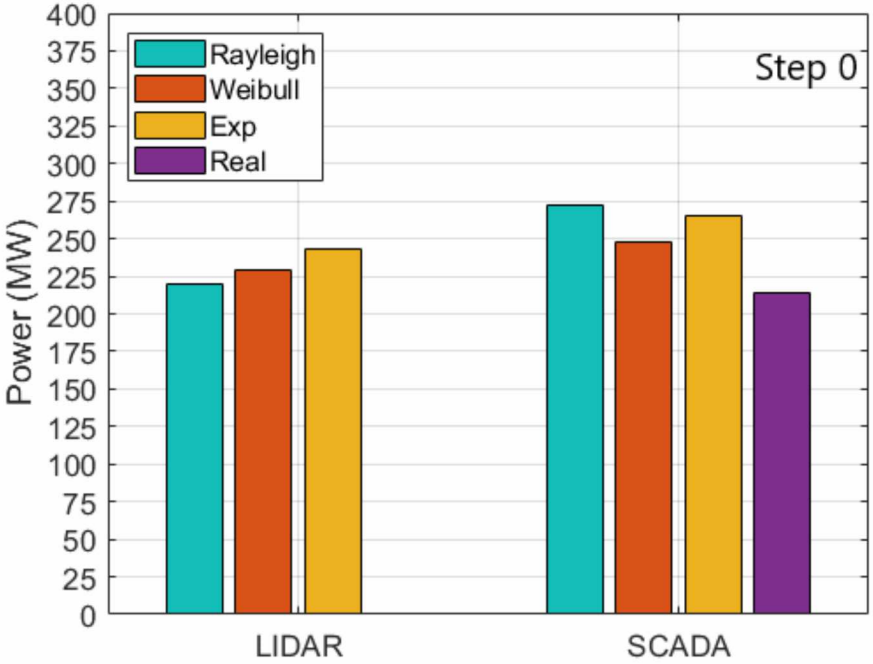

6. Results

Power production by filtering step

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	Real	Experimental Filtered LIDAR	Experimental Equivalent SCADA	Cases	Step
Power (MW.h)	214.43	243.45	265.65	29,269	0
Diff w.r.t. Exp prod		-13.5%	-23.9%		
Power (MW.h)	228.35	255.19	280.33	28,344	1
Diff w.r.t. Exp prod		-11.8%	-22.8%		
Power (MW.h)	227.72	257.16	285.24	17,877	2
Diff w.r.t. Exp prod		-12.9%	-25.3%		
Power (MW.h)	237.06	266.57	297.92	11,218	3
Diff w.r.t. Exp prod		-12.4%	-25.7%		
Power (MW.h)	158.76	199.49	246.18	7,399	4
Diff w.r.t. Exp prod		-25.6%	-55.1%		
Power (MW.h)	156.47	197.30	243.83	7,220	5

6. Results

LIDAR VS SCADA (7,220 10-min observations)

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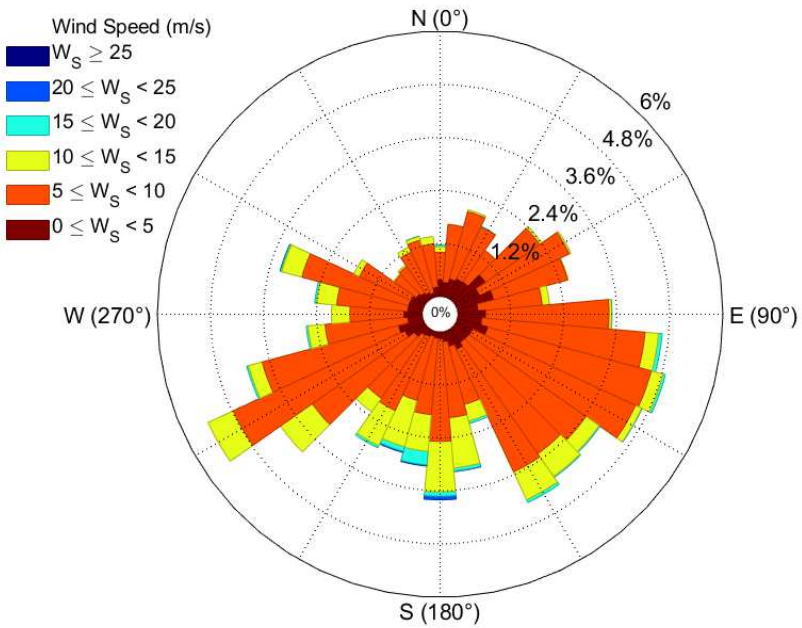
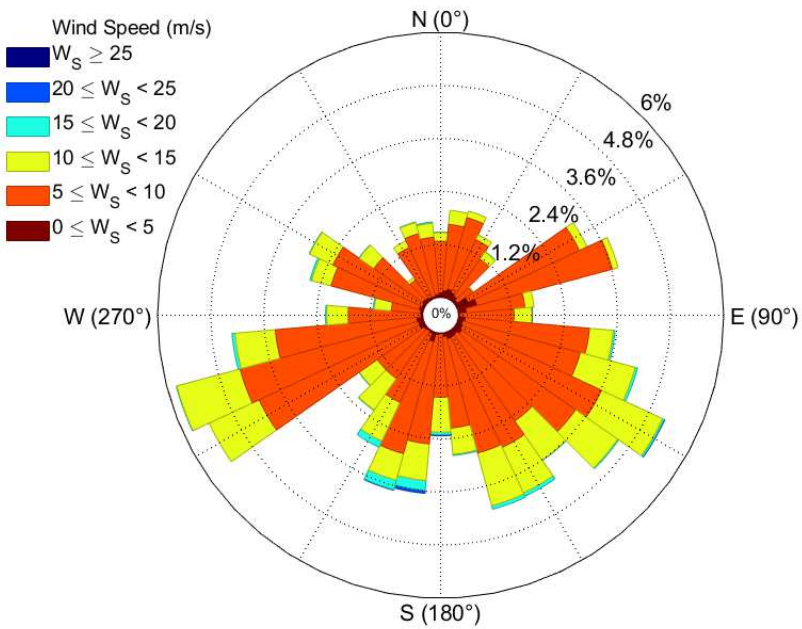
LIDAR



SCADA



7. Conclusions

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Summary

- SCADA power outputs database was reduced from 78,667 10-min measurements to 7,220 periods.
- Approach (based on [3]) to characterize the inflow conditions from SCADA wind speed measurements.
- Wind turbine sensors are not reliable enough to perform an accurate wind resource assessment of the site.
- Samples available in SCADA vary and never match theoretical values.

References

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- [1] Cover picture available at: https://www.nib.int/who_we_are/news_and_media/articles/1325/dong_inaugurates_denmark_s_largest_offshore_wind_farm
- [2] World Energy Council. “World Energy Trilemma Index 2019”, available at: https://www.worldenergy.org/transition-toolkit/world-energy-trilemma-index
- [3] A. Peña, K. Schaldemose Hansen, S. Ott, et al. “On wake modeling, wind-farm gradients, and AEP predictions at the Anholt wind farm”. eng. In: Wind Energy Science 3.1 (2018), pp. 191–202. issn: 2366-7443. url: https://doaj.org/article/1856cdc42f98479dba7a6b7d4d5e3464
- [4] Anholt Offshore Wind Farm. PDF file, brochure. Available at: https://orsted.com/en/our-business/offshore-wind/our-offshore-wind-farms