

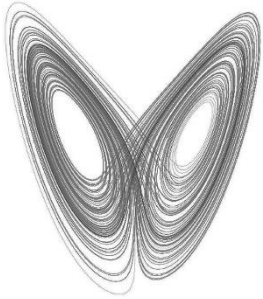


Performance Analysis of a Wind Turbine using High-Resolution SCADA Data

Potsdam, 9-10 November 2016

About Nispera

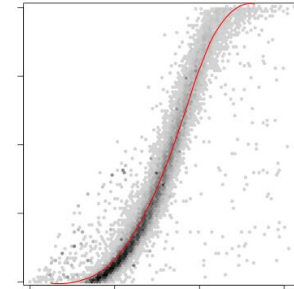
Forecasting



Monitoring Solutions



Performance Assessment

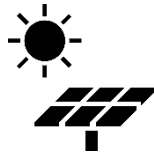


Artificial Intelligence



Nispera was founded in June 2015, by a team of experts from the energy utility sector.

Big-Data Analytics



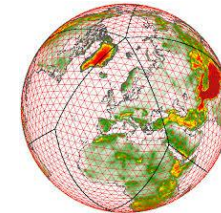
SCADA data



Market data



Numerical Weather Predictions



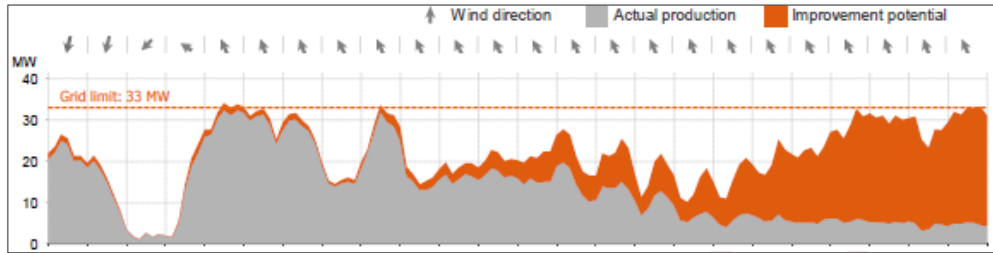
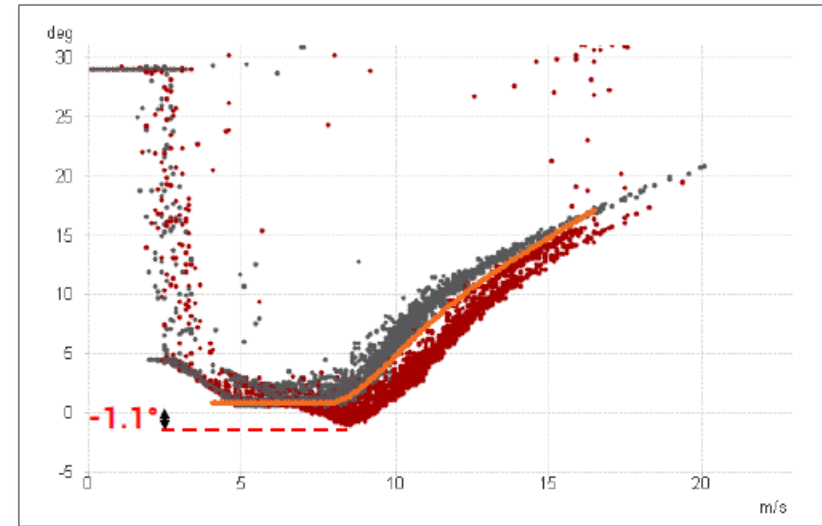
Performance Monitoring

Applications:

- Continuous (Reporting System, App, Web-Cockpit)
- Periodic (End of Warranty, Performance Assessment, etc.)

Topics covered:

- Energy Loss Analysis
- Logbook Analysis
- KPIs (Availability, Efficiency, Energy Loss Factor, etc.)
- Operational Parameters (power curves, pitch, rpm, yaw, etc.)

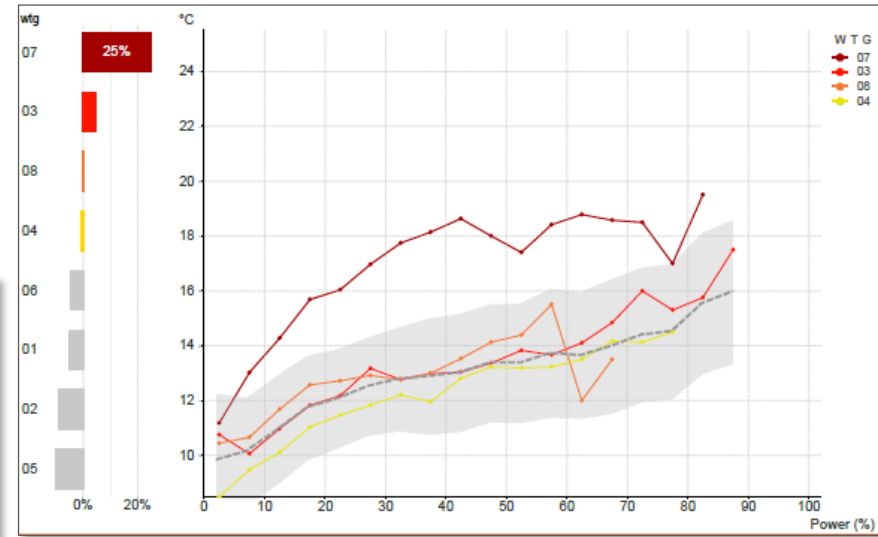


List of errors ranked by duration

Error Nr.	Description	Duration [hh:mm]
332	Max lubr. faults - generator	33:17
621	Service key	31:25
403	-	11:25
205	Short untwist CCW	04:53
150	Pitch oil temp. high	02:59
144	Hub panel temp. high	02:24
478	Pitch pos sig unstable blade 2	02:10
479	Pitch pos sig unstable blade 3	02:10
477	Pitch pos sig unstable blade 1	02:10
207	Long untwist CCW	00:56

Distribution of error's duration among the turbines (in percentage)

Error Nr.	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	
332	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
621	56	0	0	0	0	0	0	0	0	0	0	19	17	0	0	0	0	0	0	7	0	0	0
403	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
205	0	0	0	10	0	0	10	10	0	10	0	0	10	0	11	10	10	10	0	10	0	0	0
150	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
144	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
478	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
479	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
477	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0
207	0	0	0	0	0	0	0	0	0	0	49	0	0	0	0	0	0	0	0	51	0	0	0



Data Used in the Analysis

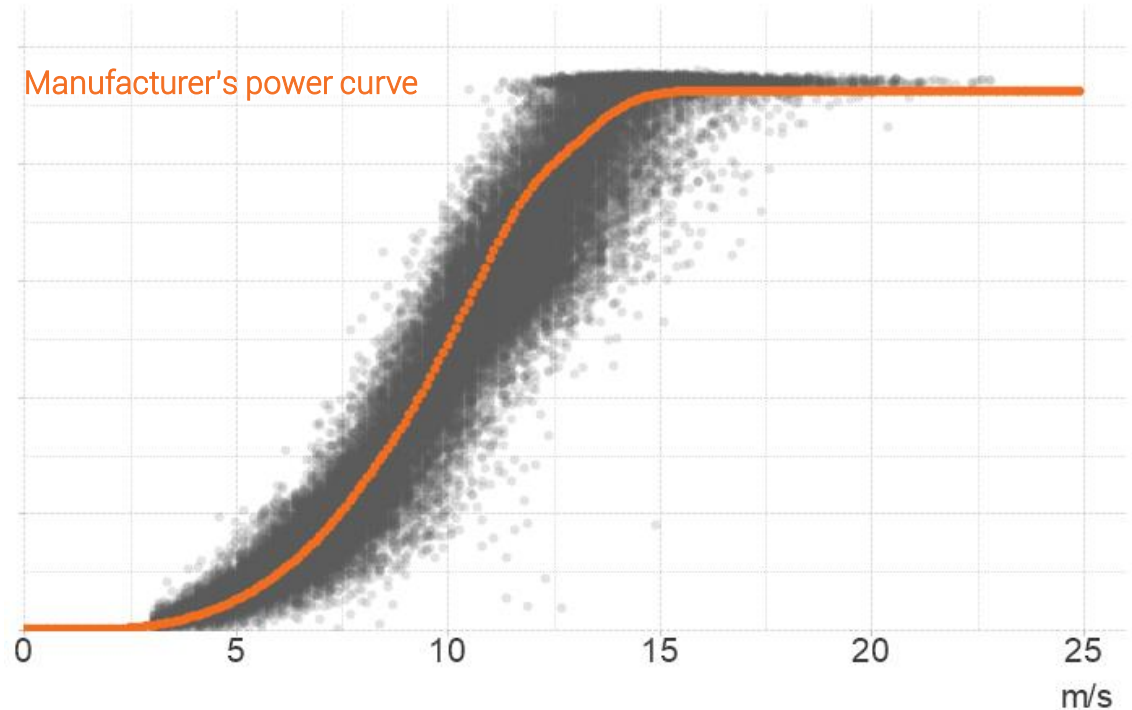
Signals used for this analysis:

- Active power
- Wind speed
- Wind direction
- Nacelle position

Resolution: 2 seconds (approx.)

Analysis period: 10 days

Data volume: > 2 million data points

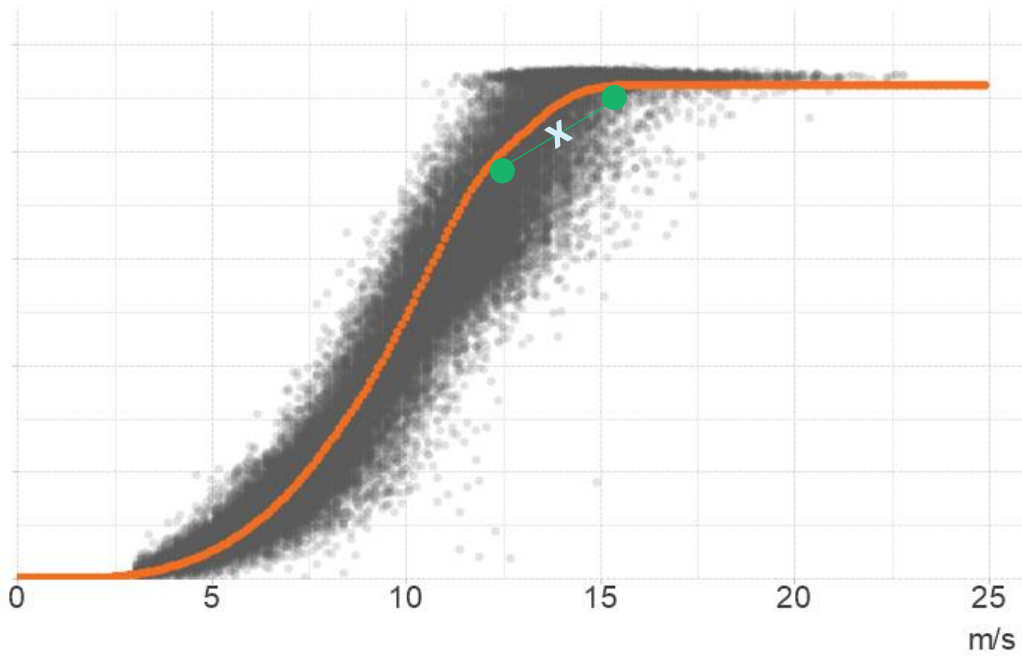


Keywords:

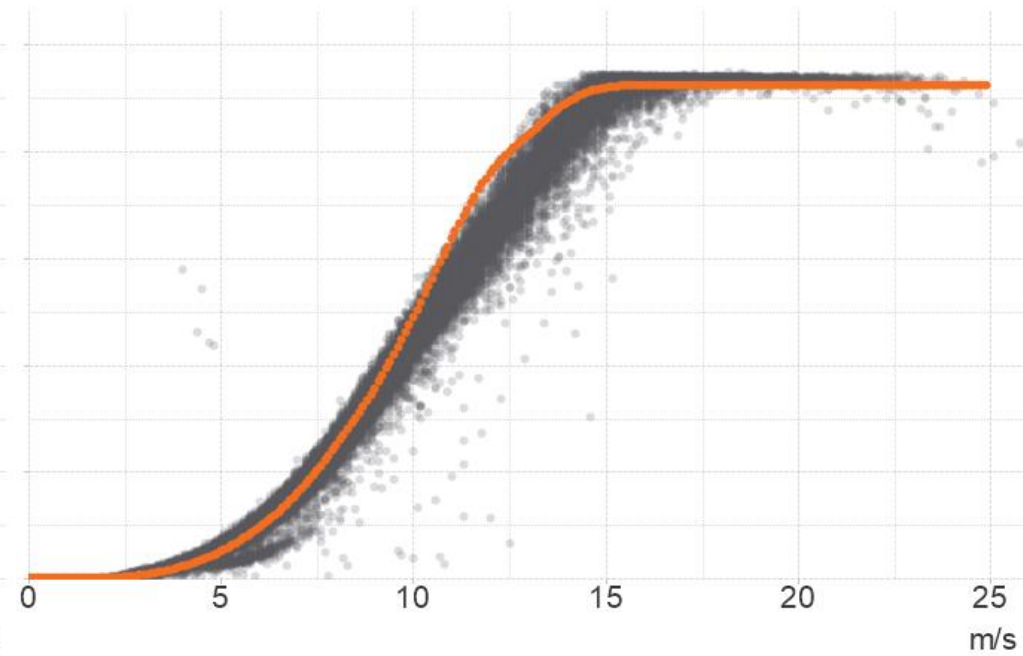
- Manufacturer's power curve
- IEC 61400-12-2: 2013 procedure
- 10-minutes averaging
- Raw SCADA data

10-min Averaging Effect

Raw data



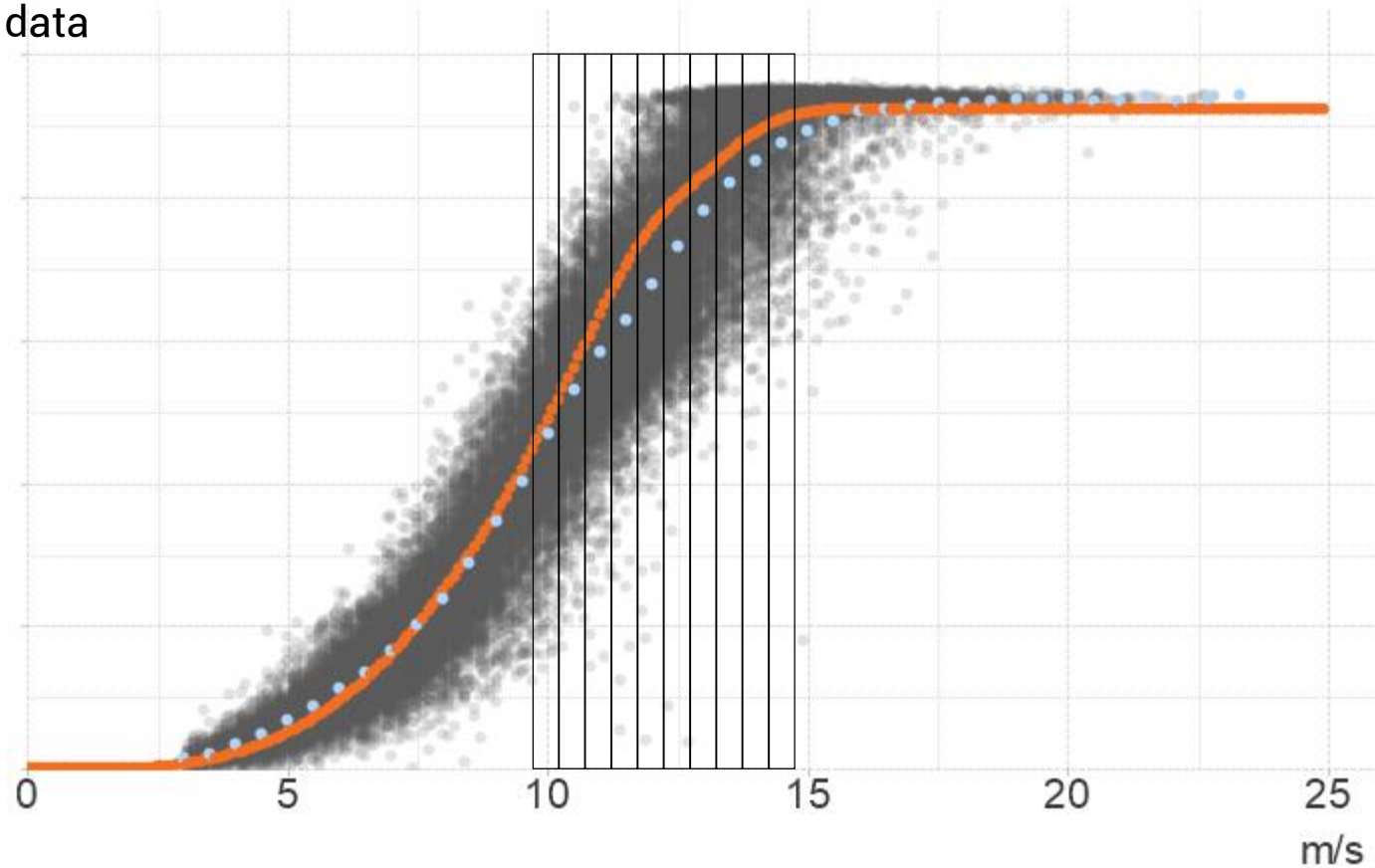
10-min averages
(obtained from raw data applying time averaging)



IEC 61400-12-2 Procedure

'method of bins' (0.5 m/s bins)

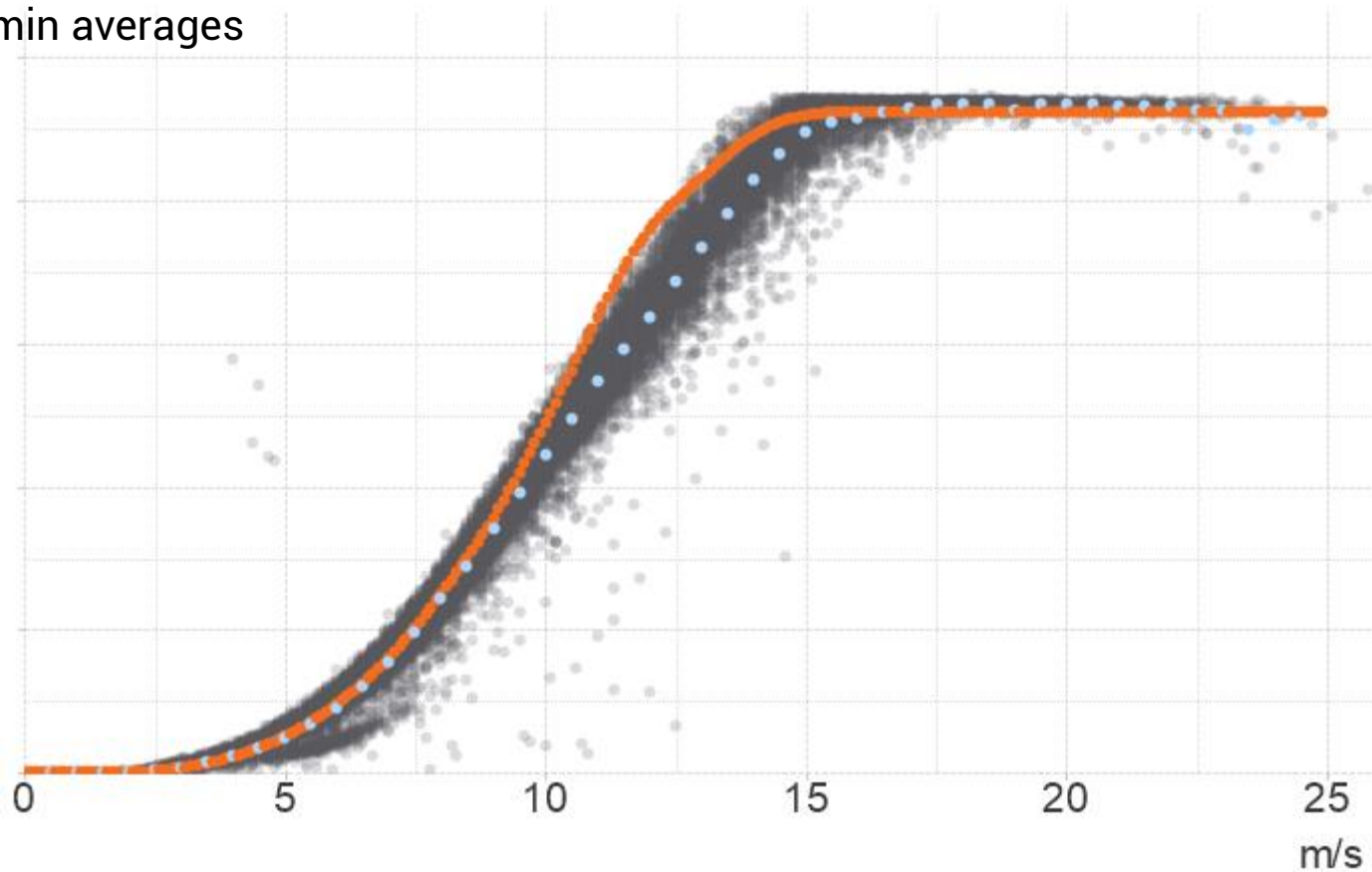
applied on raw data



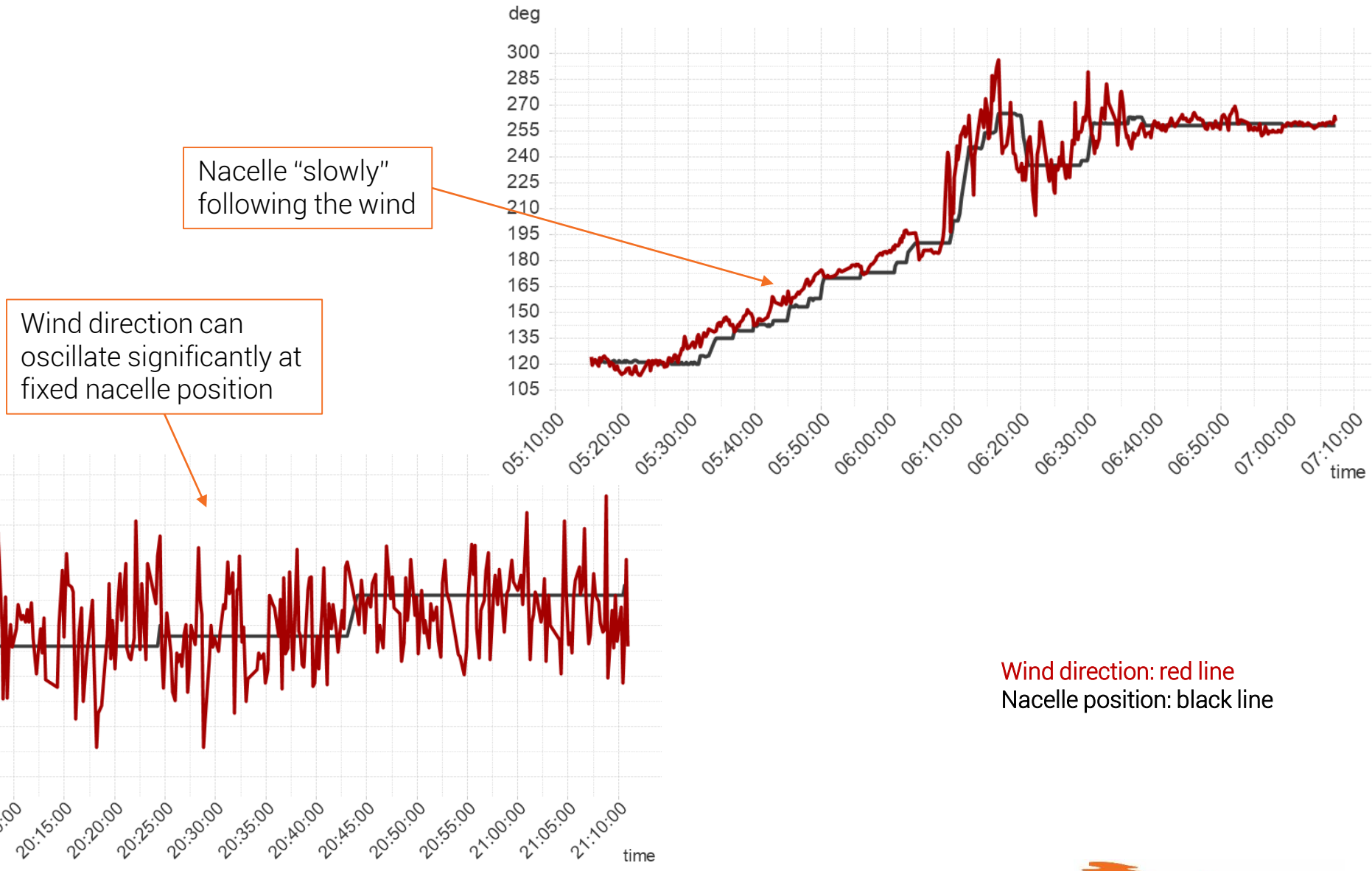
IEC 61400-12-2 Procedure

'method of bins' (0.5 m/s bins)

applied on 10-min averages



Dynamic Turbine Behavior



Data Filtering

The proposed filters can be regarded as a definition of stationary inflow conditions (max fluctuation of wind speed and direction during a certain period)

“Filter 1”:

Wind fluctuation during 2 minutes:

- speed max ± 1.0 m/s
- direction max $\pm 10^\circ$

“Filter 2”:

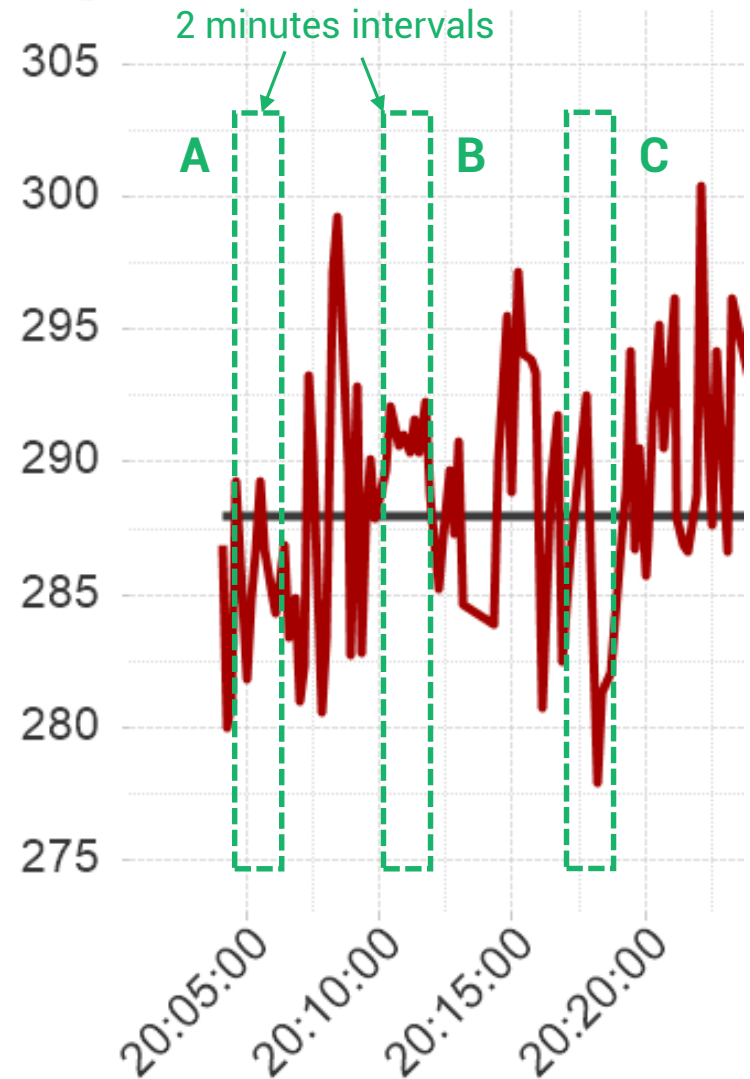
Wind fluctuation during 2 minutes:

- speed max ± 0.5 m/s
- direction max $\pm 5^\circ$

Wind Direction	Interval A	Interval B	Interval C
Filter 1	OK	OK	NO
Filter 2	NO	OK	NO

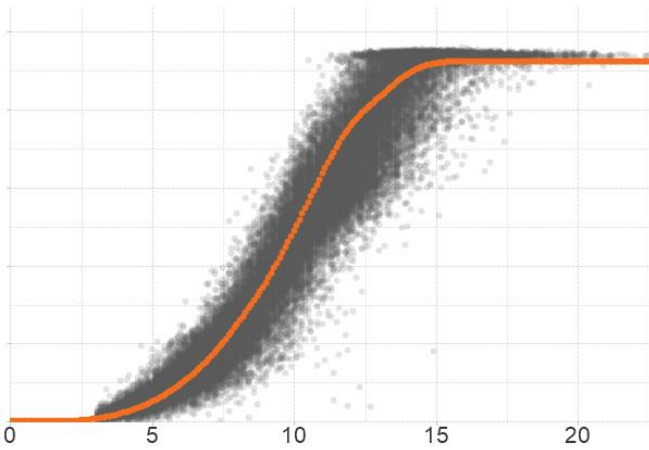
Nacelle Position deg

Wind direction: red line
Nacelle position: black line



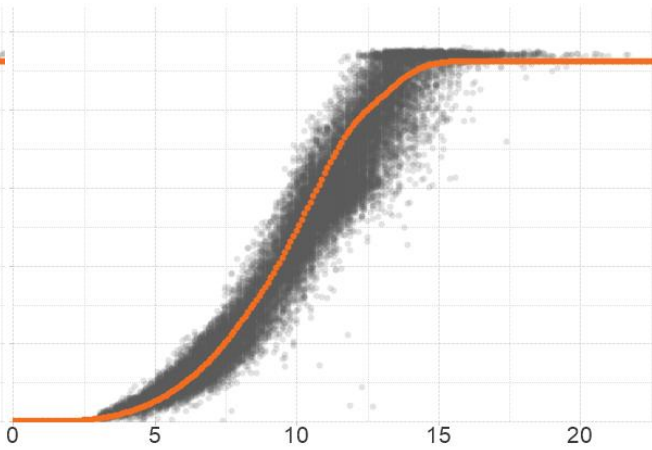
Power Curve Filtering

“Raw” Power Curve



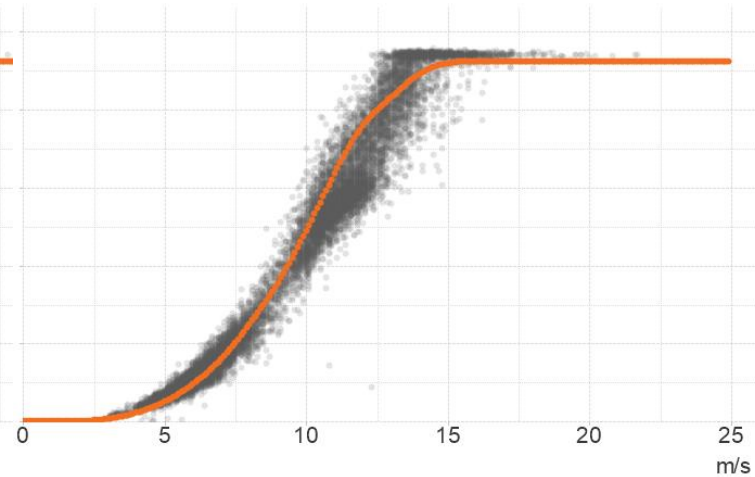
“Filter 1”:

- Wind fluctuation during 2 minutes:
- intensity max ± 1.0 m/s
 - direction max $\pm 10^\circ$



“Filter 2”:

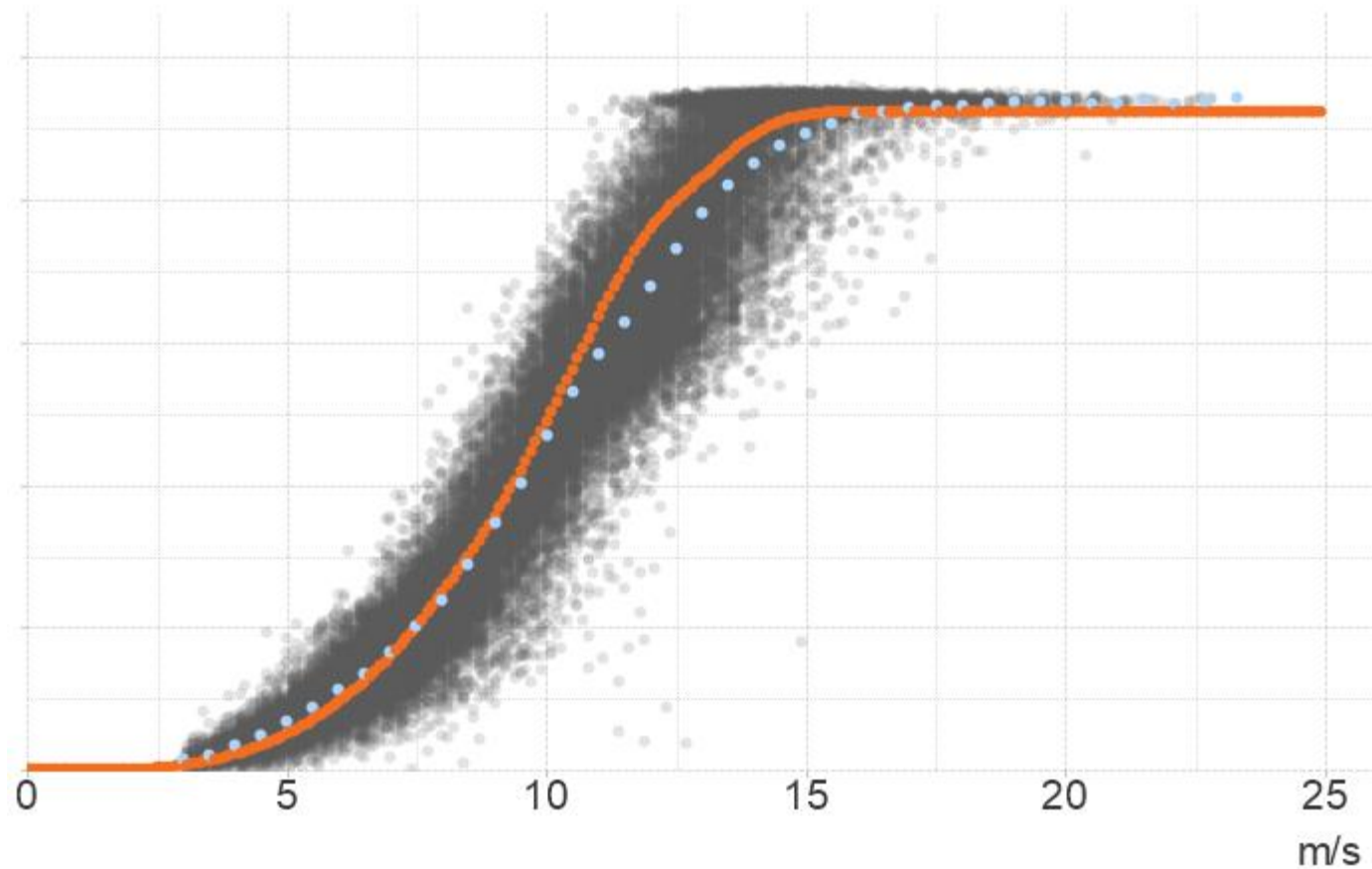
- Wind fluctuation during 2 minutes:
- intensity max ± 0.5 m/s
 - direction max $\pm 5^\circ$



Power Curve: Raw

'method of bins' (0.5 m/s bins)

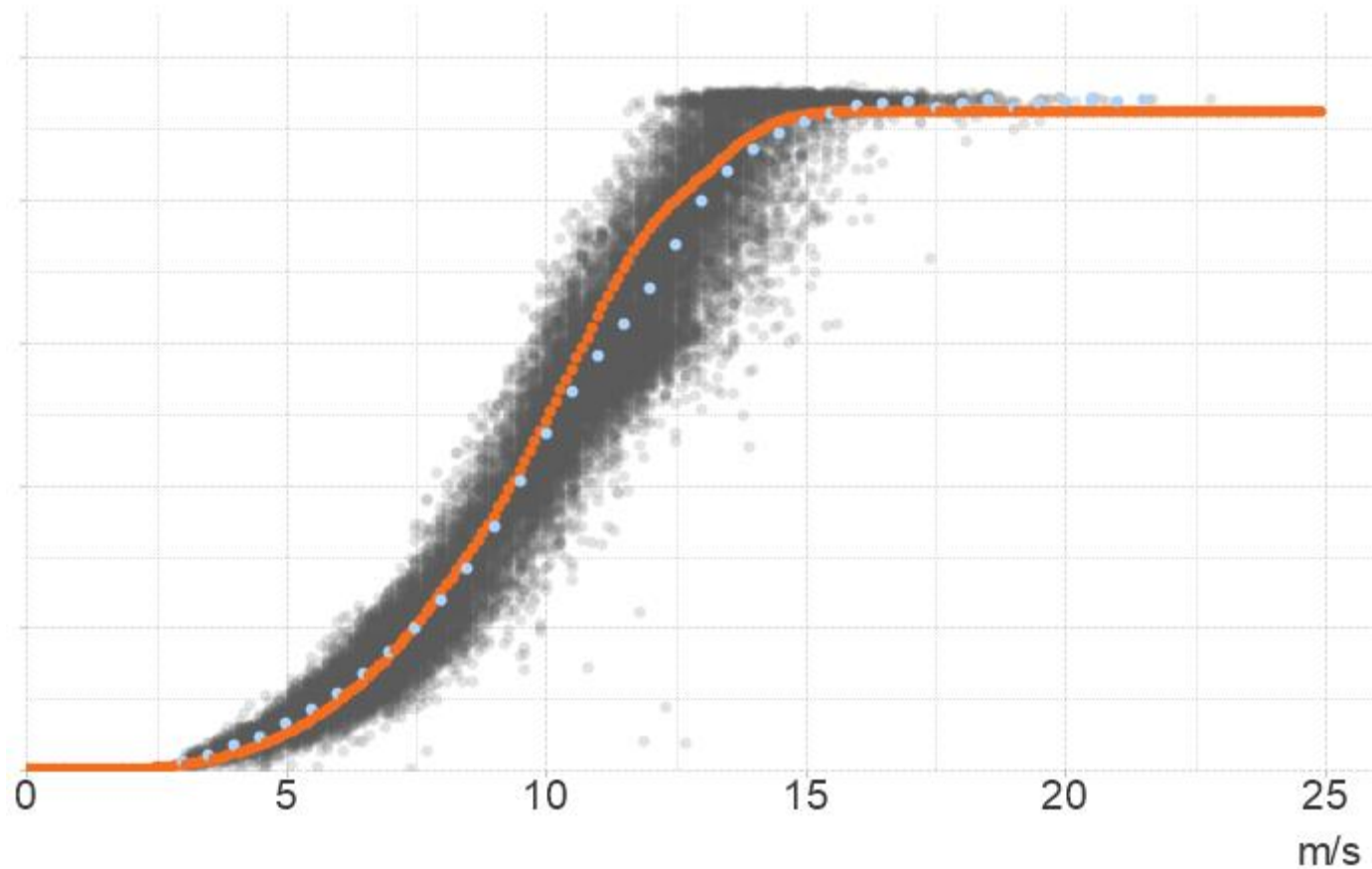
using raw data



Power Curve: Filter 1

'method of bins' (0.5 m/s bins)

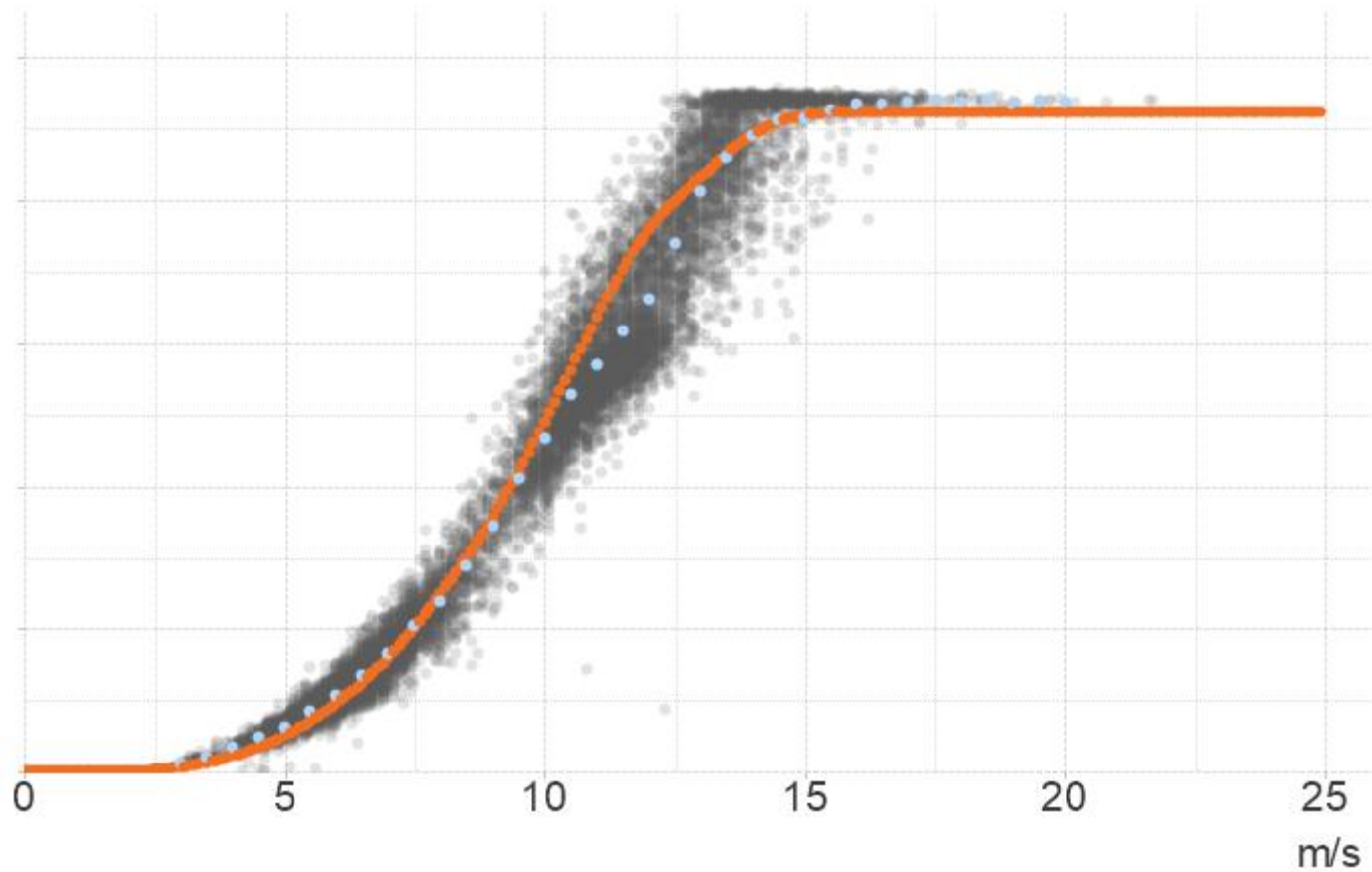
using Filter 1



Power Curve: Filter 2

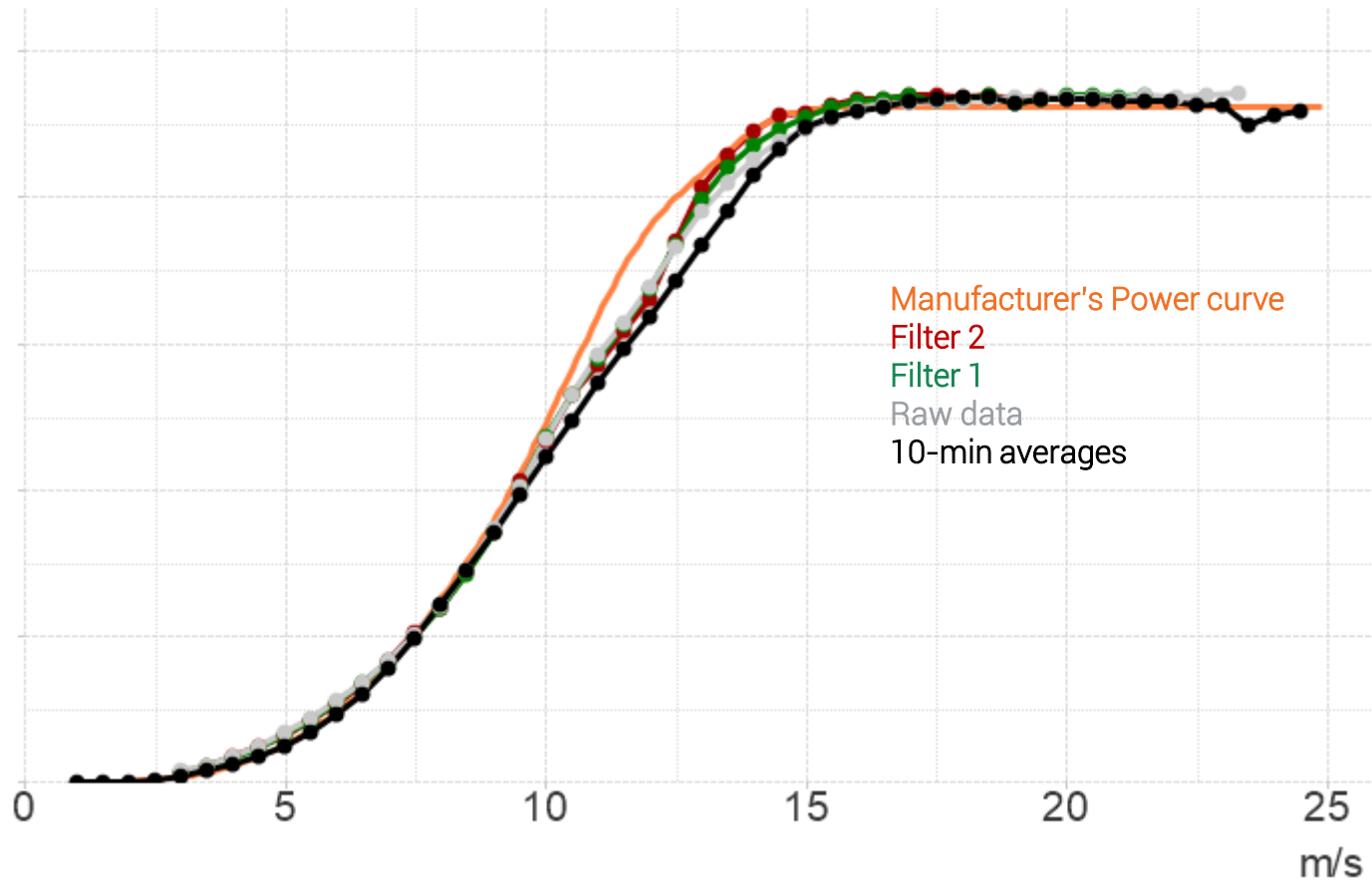
'method of bins' (0.5 m/s bins)

using Filter 2



Comparison

The 'method of bins' (0.5 m/s bins) is applied according to IEC 61400-12-2: 2013



Conclusions

- 10-minutes averaging introduces errors in power curve assessment
- High-frequency measurements ($\sim 0.5\text{Hz}$) can help reducing the 10-minutes averaging effects
- Filtering of raw data (applying stationary conditions) provides deeper insights into real turbine performance



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