Tipspeed

Wind EUROPE TECHNOLOGY WORKSHOP 2024 10-11 JUNE DUBLIN

Physics based turbine performance assessment using wind flow models.

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Poster P007

“Is it underperformance
or lack of resource?”

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or lack of resource?”

Knowing the absolute performance is hard

Finding optimization opportunities is challenging

Changes over time can be missed

A digital twin from *resource* to *production*

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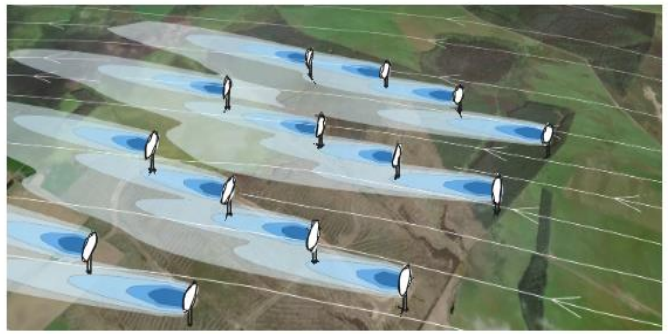
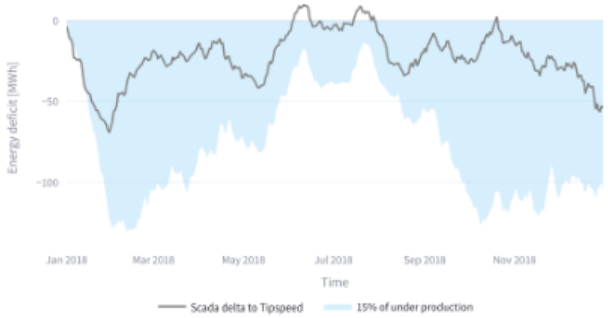
Set-up wind farm Digital twin



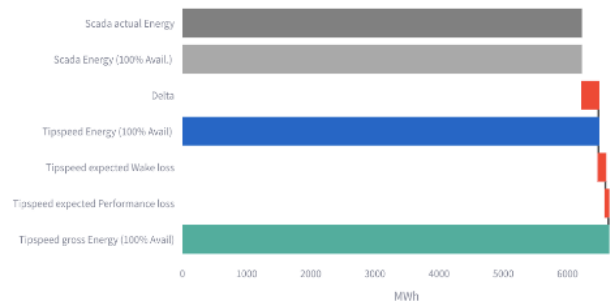
10 min time series as independent references for wind, losses and power, at each turbine

Compare to asset (SCADA)



Predicted vs actual power directly compared for each turbine, across entire site

Categorize & quantify losses



Enables assessment, quantification and root causes investigation of underperformances

Technology stack (patent pending)

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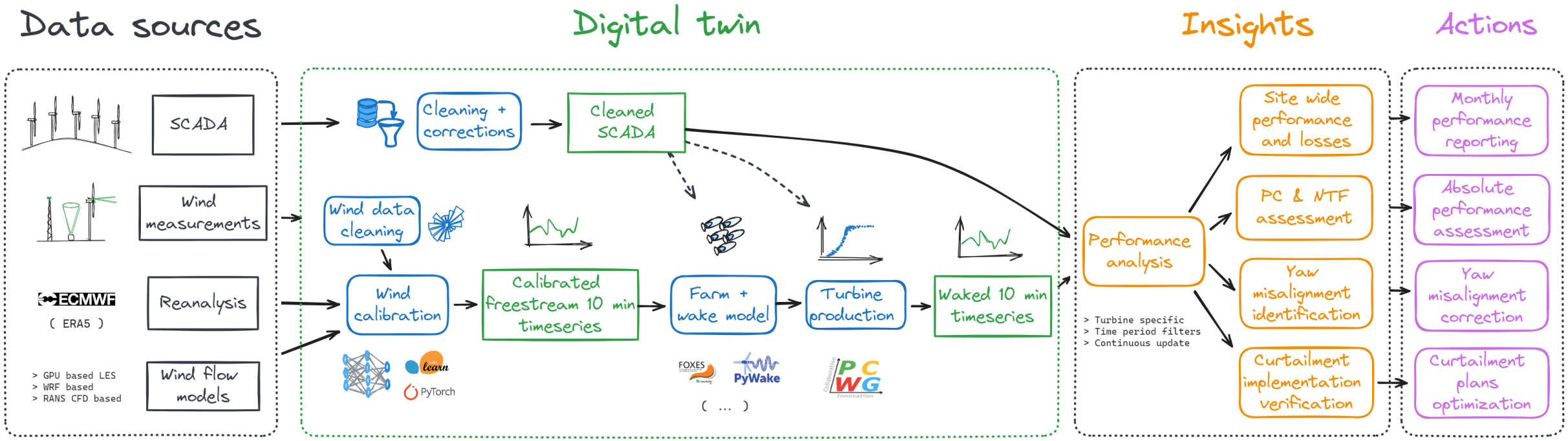


Adapts to different scenarios
Combines existing data, models & tools

10 min timeseries at turbine level
Automated workflows optimized for 10 min timeseries at turbine level

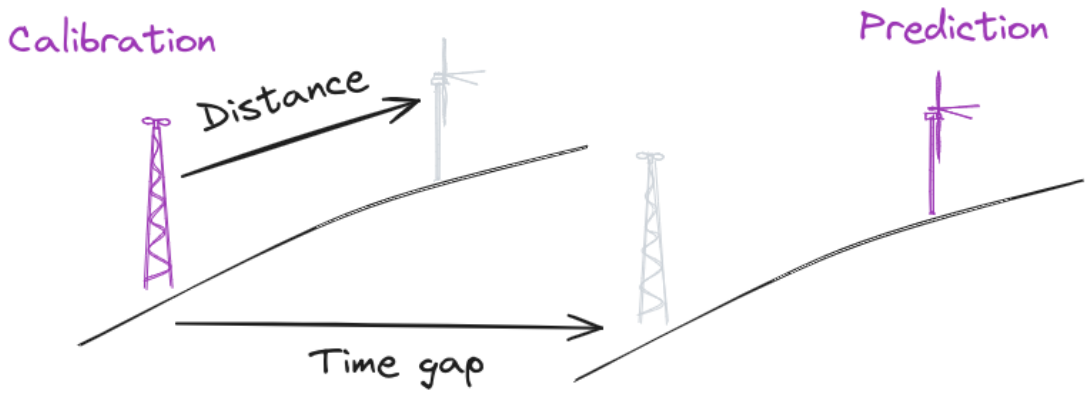
Goal = real world applications
Analyses & Validations based on all conditions including wakes

Validation method and dataset

Goal
Evaluate wind speed accuracy during operational period

Digital twin setup
Wind speed calibrated only with pre-construction measurements
Wake model tuned with 1 year of production data

Procedure



Validation data
12 calibrated operational sensor (masts, nacelle lidar, spinner anemometers) across 4 farms
Turbines in operation, including wakes
Durations ranging from 3 weeks to 1 year

Type	Distance	Time gap
Complex	1.5 km	4 years
Complex	1.6 km	3 years
Simple	0 km	1 year
Simple	4 km	10 years

Metrics calculated on 10 min timeseries
Mean wind speed bias, Mean absolute error, Correlation coefficient

Wind validation results including wakes

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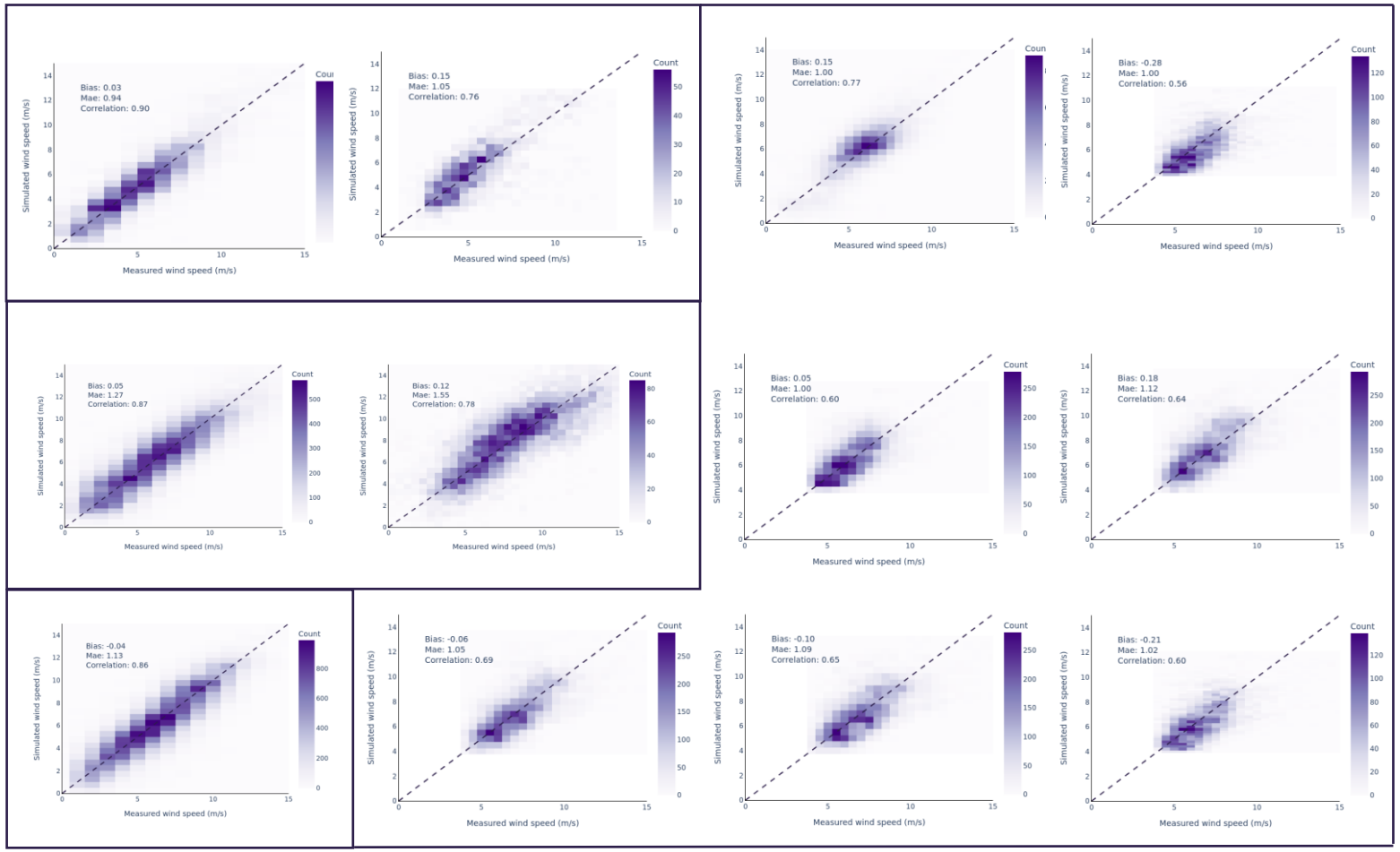
Results *	
Bias (m/s)	0.02 ± 0.08
Absolute bias (m/s)	0.09 ± 0.04
MAE (m/s)	1.14 ± 0.19
Correlation (-)	0.79 ± 0.10

*** Site aggregated, then averaged**



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What real world performance applications can be achieved?

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From wind farm performance screening to root cause analysis

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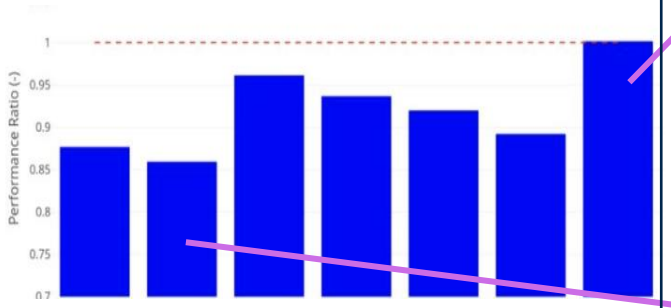
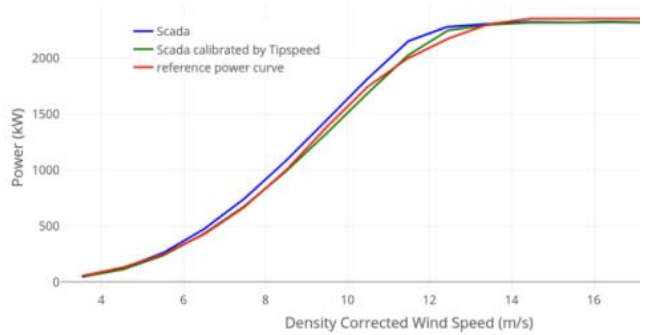
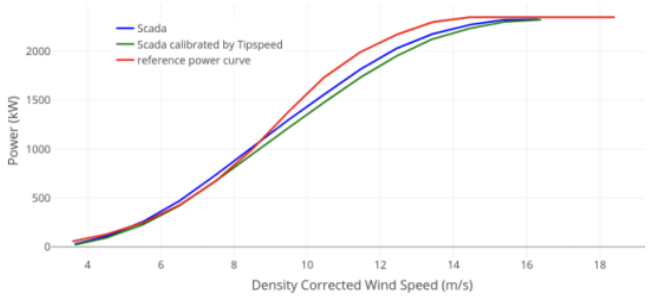
Step 1: assess performance ratios

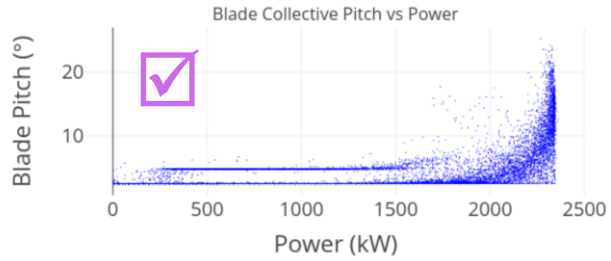


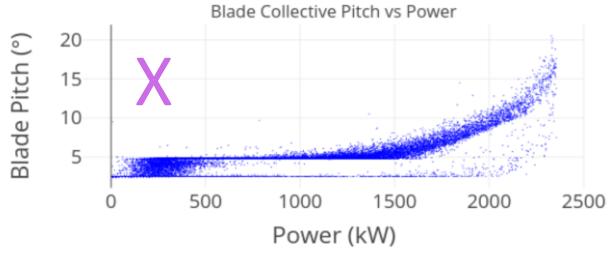
Step 2: check individual PC





Step 3: identify root cause





Using Tipspeed data on all turbines simultaneously allowed to detect unknown under performances and uncover potential root cause (pitch). OEM engaged for resolution.

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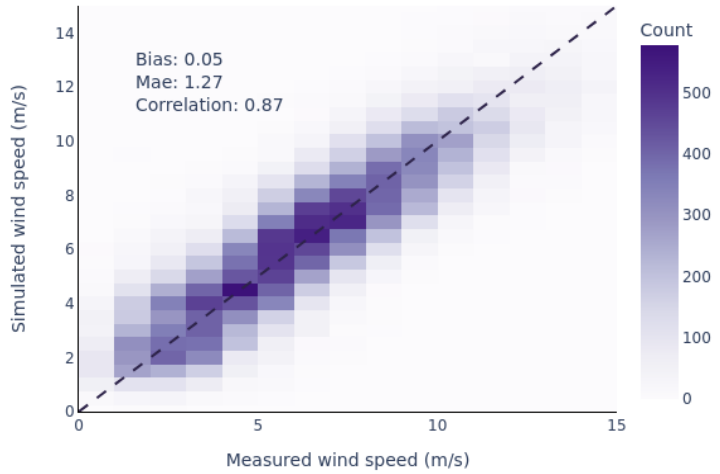
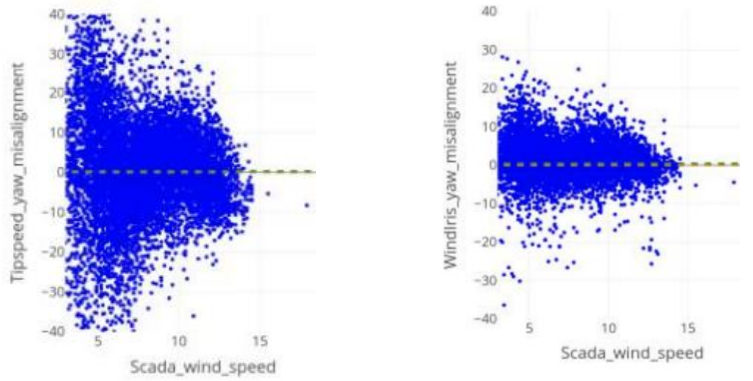
10 min wind speed accuracy



Yaw misalignment

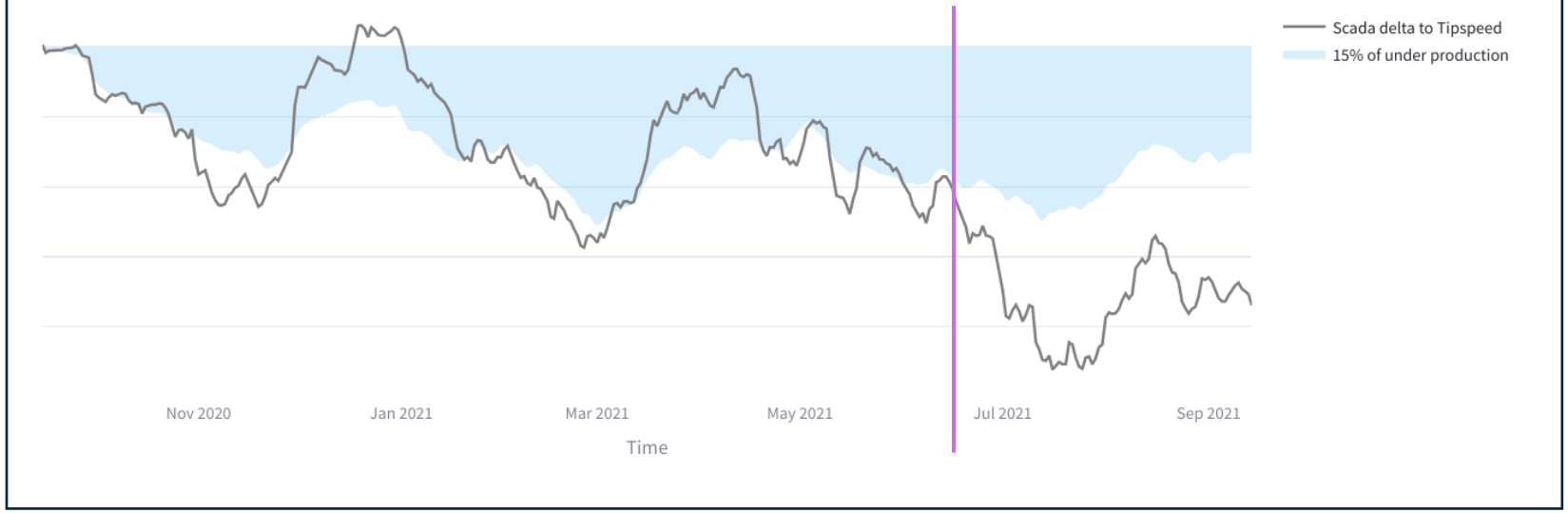


Tipspeed: 0.3° **Nacelle lidar: 0.4°**

Site	Complex terrain.
Context	Suspicion of performance issues. Past nacelle lidar campaign showed good performance on target turbine.
Test method	Blind validation of wind speed accuracy against lidar. Ability to detect under performance.

Validating the detection of a performance issue over time

Tipspeed power prediction vs SCADA over time



Tipspeed correctly identified under performance (turbines, periods and magnitude)

Site	Complex terrain.
Context	Significant performance issues previously diagnosed. Unperformance events and magnitude known.
Test method	Blind validation of Tipspeed prediction of impacted turbines, time periods and magnitude of underperformances.

Validation of yaw misalignment detection and its impact on performance

Yaw misalignment change over time

Tipspeed blindly predicted the dates of events, and the misalignments before/after offsets.

Site	Simple terrain.
Context	Site dedicated to yaw experiments. Misalignments known to customer, before and after offsets applied.
Test method	Blind validation of Tipspeed prediction of pre/post misalignments, and dates of events.

Technology and validation next steps

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- **Continue to implement new validation methods for long duration wind predictions within operating wind farms.**
- **Report on our on-going multi-site validation of yaw misalignment predictions.**
- **Implement data fusion of the digital twin together with sensors, in the case where reliable operational data is available.**

A special thanks to our early partners for their trust

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