WindESCo

ENGIE

Yaw Misalignment Validation Study

Using LiDAR

Release Month: 2021-02

Overview

WindESCo was contracted by a leading European IPP to validate Find, Fix, Measure SCADA data-based yaw misalignment results with results from nacelle LiDAR-based campaigns conducted by the IPP.

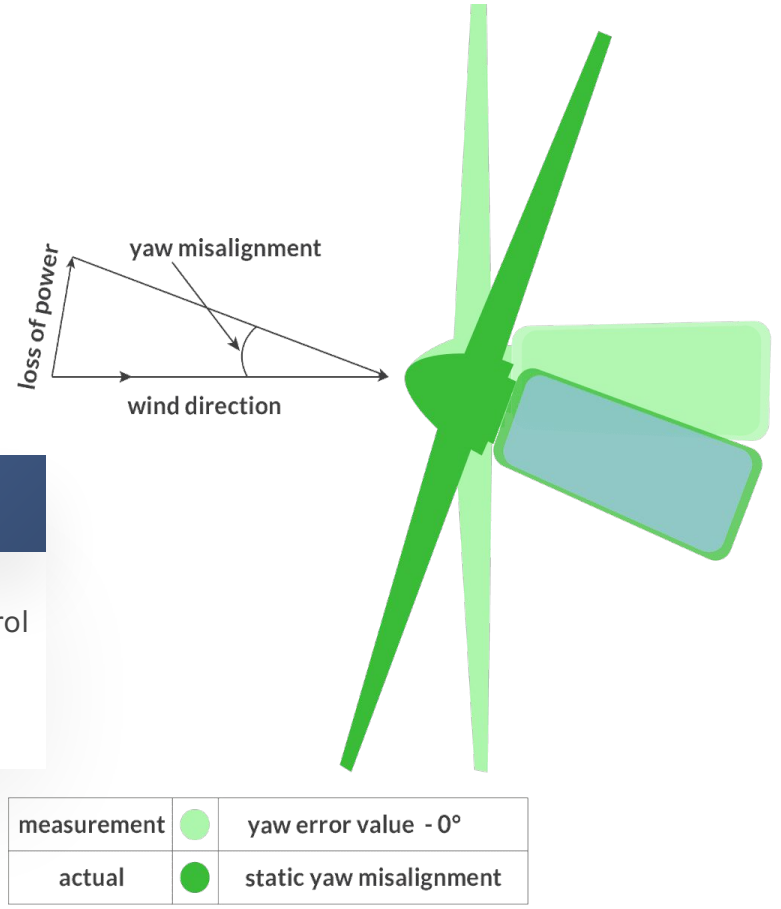
SCADA data was provided to WindESCo for 7 turbines for which the IPP had conducted LiDAR campaigns.

> *"WindESCo's calibration process makes it possible to determine the absolute value of static yaw misalignment. We are now confident it can help us save time and cost to re-align our wind turbine and secure our revenues"*

Nicolas Girard
Head of Analytics, DARWIN, Engie

What is Static Yaw Misalignment?

- Turbine, on average, are misaligned with respect to wind direction
- Leads to loss of power and slight increase in load



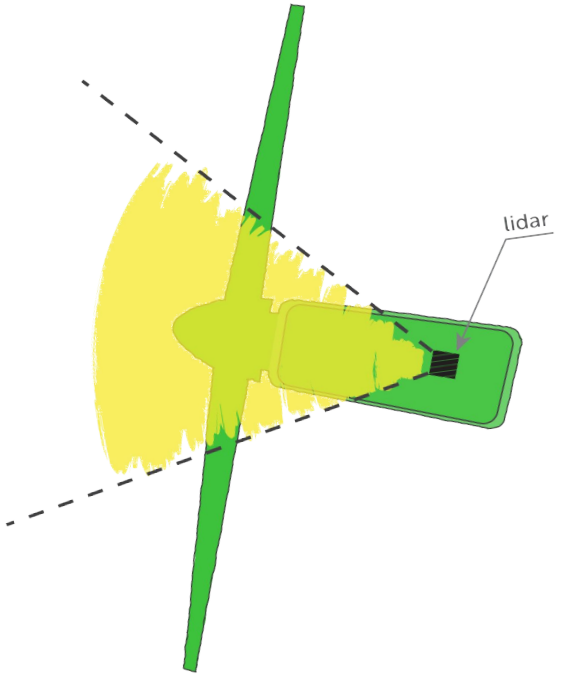
Cause 1	Cause 2	Cause 3
Wind vane not aligned with the turbine axis	Flow distortion – wind vane is located behind the rotor	Wrong yaw offset parameter used in the control system

WindESCo

About LiDAR

Source: Vaisala

Light detection and ranging (LiDAR) systems can be mounted on top of the nacelle to gauge wind direction in front of the rotor. LiDAR uses laser beams directed upwind of the turbine to determine wind speed and yaw misalignment.



Features

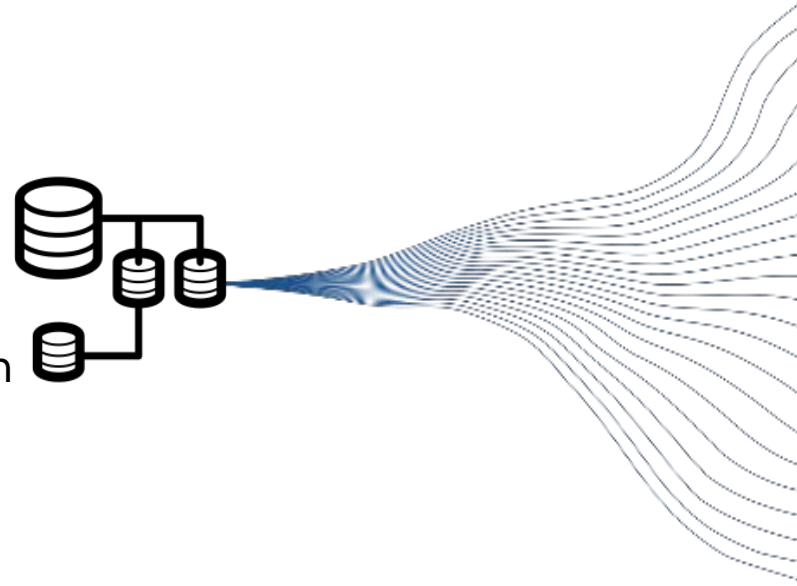
- Mostly used for operational power performance testing
- Can also be used for determining yaw misalignment
- Requires physical installation on every turbine to be optimized
- Must be accurately aligned with the turbine axis by trained personnel
- Data needs to be synchronized with SCADA data for meaningful analysis
- Equipment must be sent for periodic maintenance

WindESCo Find, Fix, Measure

To enable wind plant owners create more value from SCADA data, without the need to install additional hardware, WindESCo commercially deployed its yaw misalignment algorithm after 3 years of development and testing

Features

- Based on high speed SCADA data from 10 - 15 tags
- No additional hardware required
- OEM / turbine model agnostic
- Requires 2 - 3 months of data to give accurate estimates
- Since there no SCADA data standard, we have seen a lot of variation in SCADA data from different OEMs/models. Therefore, we require 2 pre-determined yaw offsets to accurately train our models for each site
- Applied to the following OEMs: GE, Vestas, Siemens, Gamesa, Acciona, Suzlon, Nordex, Clipper and Mitsubishi
- Successfully applied to more than 1.000 turbines in 2020



Project Details

Two sites were selected by the IPP to test Find, Fix, Measure yaw misalignment algorithm. Both sites previously had LiDAR campaigns.

1

Location	Europe
Number of Turbines	4
LiDAR Campaign Period	3 months
LiDAR Type	Vaisala-Leosphere WindCube® Nacelle

2

Location	Europe
Number of Turbines	3
LiDAR Campaign Period	8 months
LiDAR Type	Vaisala-Leosphere WindCube® Nacelle

Result Qualification

Since results from the LiDAR and Find, Fix, Measure algorithm were calculated based on data over varying periods, the following qualification criteria was used. Results based on data less than 60 days in length were disqualified for comparison due to high uncertainty.

Data Period	Qualified
0 - 30 days	No
30 - 60 days	No
> 60 days	Yes

Project 1 - Results

Turbine Number	LiDAR	Find, Fix, Measure
1	-2,0°	-3,3°
2	-1,1°	-2,5°
3	-0,1°	-1,7°
4	-0,2°	-0,8°
Days at Offset	> 60	> 60
Qualified	Yes	Yes

Campaign length = 3 months
Number of changes in yaw offset during campaign = 0
Yaw offsets were not changed on this project during the campaign

Project 2 - LiDAR Results

Yaw Misalignment						
Turbine Number	Before 2018-08-02	2018-08-02 to 2018-10-04	2018-10-04 to 2018-10-17	2018-10-17 to 2018-10-24	2018-10-24 to 2018-12-11	After 2018-12-11
1	-6,7°	+4,8°	+9,4°	0°	-5,8°	0°
2	+2,7°	+2,7°	+4,9°	0°	-5,1°	0°
3	-2,2°	+3,4°	+7,5°	0°	-5,5°	0°
Days at Offset	> 60	>60	< 30	< 30	30 - 60	> 60
Qualified	Yes	Yes	No	No	No	Yes

Yaw Offset Applied for turbine 1	+11,5°	+4,6°	-9,4°	-5,8°	+5,8°
Yaw Offset Applied for turbine 2	0,0°	+2,2°	-4,9°	-5,1°	+5,1°
Yaw Offset Applied for turbine 3	+5,6°	+4,1°	-7,5°	-5,5°	+5,5°

Campaign length = 8 months
Number of changes in yaw offset during campaign = 5
Points with data less than 60 days were not qualified due to limited length of campaign

Project 2 - Find, Fix, Measure Results

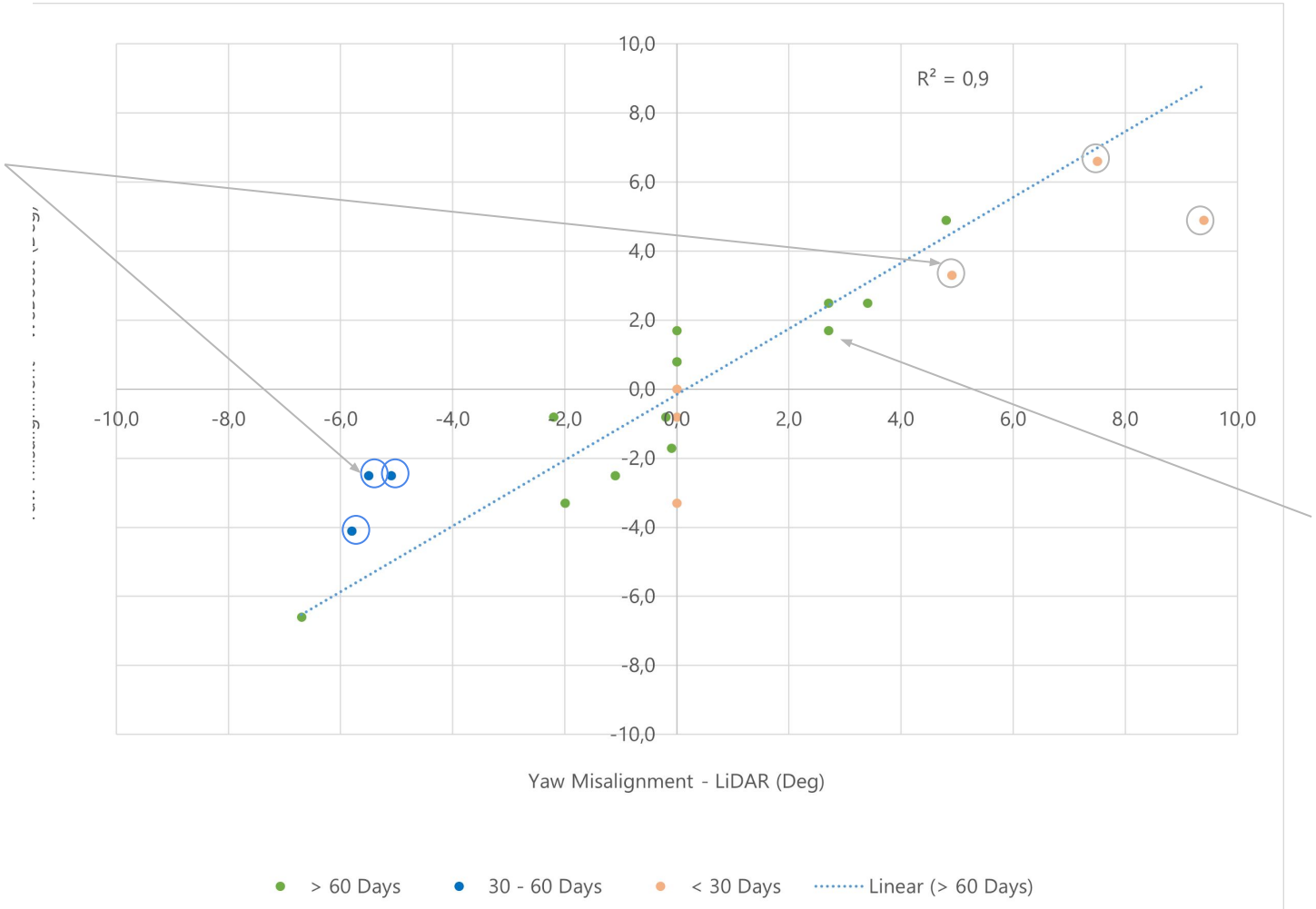
Yaw Misalignment						
Turbine Number	Before 2018-08-02	2018-08-02 to 2018-10-04	2018-10-04 to 2018-10-17	2018-10-17 to 2018-10-24	2018-10-24 to 2018-12-11	After 2018-12-11
1	-6,6°	+4,9°	+4,9°	-0,8°	-4,1°	0,8°
2	+1,7°	+2,5°	+3,3°	-3,3°	-2,5°	0,8°
3	-0,8°	+2,5°	+6,6°	0°	-2,5°	1,7°
Days at Offset	> 60	>60	< 30	< 30	30 - 60	> 60
Qualified	Yes	Yes	No	No	No	Yes

Yaw Offset Applied for turbine 1	+11,5°	+4,6°	-9,4°	-5,8°	+5,8°
Yaw Offset Applied for turbine 2	0,0°	+2,2°	-4,9°	-5,1°	+5,1°
Yaw Offset Applied for turbine 3	+5,6°	+4,1°	-7,5°	-5,5°	+5,5°

Campaign length = 8 months
Number of changes in yaw offset during campaign = 5
Points with data less than 60 days were not qualified due to limited length of campaign

Find, Fix, Measure / LiDAR Comparison

Points where less than 60 days of data was available to provide results were disqualified and show a poor correlation due to high uncertainty in both Find, Fix, Measure and LiDAR results



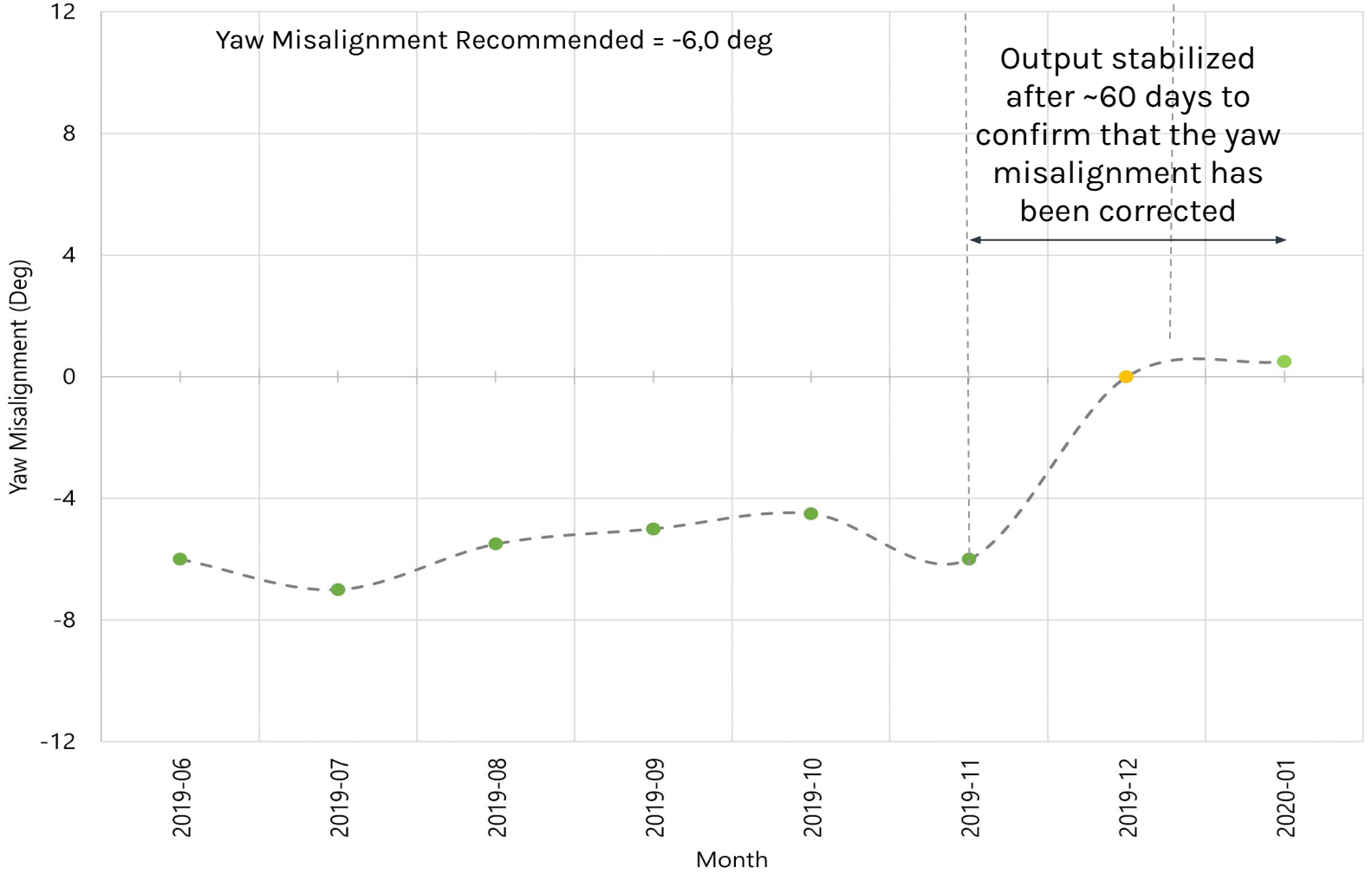
Points where greater than 60 days of data was available to provide results were qualified and show a very good correlation with an R2 of 0.9 due to low uncertainty in both Find, Fix, Measure and LiDAR results

WindESCo

Example of Find, Fix, Measure Output

Monthly values of yaw misalignment provided based on SCADA data.

Allows owners to detect changes in yaw misalignment in 30 - 60 days depending on SCADA data sampling period.



WindESCo

Conclusion

Find, Fix, Measure Yaw Misalignment application was approved by the IPP for use in their company

Data Sample Period

For Find, Fix, Measure yaw misalignment to converge requires more than 60 days of SCADA data. There is high uncertainty even in LiDAR results below 60 days.

Comparison with LiDAR

The IPP chose Find, Fix, Measure to scale up on their portfolio

Accurate

Find, Fix, Measure results matched the LiDAR results at an R-square value of 0,9

Higher ROI

Find, Fix, Measure provides owners with a higher return on investment compared to the LiDAR, which is difficult to manage at scale due to cost and resources required

WindESCo

Your Ideal Optimization Solution Partner

Wind is complex. Accurate analysis of the existing SCADA data requires a combination of domain expertise, engineering models and machine learning techniques, all while taking into account differences in turbine models. It's important to find a partner with demonstrated expertise to help you optimize your wind project effectively.

Contact us

contact@windesco.com