

A Co-located Lidar, Advanced Sodar, IEC Met Mast Cross-Validation Analysis

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Ecofys WTTS performed a cross-correlation analysis using an advanced SoDAR remote sensor, against a co-located Windcube V2. LiDAR and Met Mast MM01. The measurements were performed at Test Site Lelystad and the investigation and report is based on the three datasets derived from the ongoing co-located measurement data gathered in the spring of 2016.

The cross-validation analysis of the SoDAR remote sensing device is based on its correlation with the measurements gathered from an IEC compliant Met Mast, with 120 meters of height, located in position #1 143 meters away from the SoDAR at Test Site Lelystad (MM01) and additionally a Windcube V2 LiDAR measuring next to the SoDAR.

{MAP omitted}

MM01's includes four measurement heights between 40 and up to 120 meters (e.g. 40, 80m, 100m, 120m), characterised by two large open valid wind sectors, one ranging from the north-west to south-west, and the second one towards the east.

For the cross-validation test, the target is to gather at least 180 hours of valid data with 3 data points per 0.5 m/s bin between 4-12 m/s. All additional concurrent valid data points above these bins (e.g. any valid data points between 12 and 16m/s bin) will be taken into account.

The validation data analysis evaluates the accuracy of the SODAR measurements based on two international wind industry standards:

- IEC 61400-12-1 validation procedure and uncertainty evaluation
- Based on the NORSEWInD validation criteria (modified)

Criterion	Category	NORSEWI _{ND} Acceptance WTTs Threshold for Replacement Acceptance of IEC-compliant Cup Anemometry	Ecofys Threshold for Field Measurements
Number of valid data points	4-8m/s	>200	
	8-12 m/s	>200	
	ALL	>600	
Percentage of data points that exceed 0.5	ALL	<10%	n/a
Linear regression slope	4-8m/s	0.98-1.01	n/a
	8-12 m/s	0.98-1.01	n/a
	Variation in slope	<0.015	n/a
	ALL	0.98-1.01	0.98-1.02
Linear regression – R ²	4-8m/s	>0.98	n/a
	8-12 m/s	>0.98	n/a
	ALL	>0.98	>0.95

Table 1: Ecofys WTTs Acceptance Thresholds, based on NORSEWI_{ND} criteria [2]

Cross-Validation test definition: The cross-validation procedure evaluates the absolute error and the quality of the linear regression between the SoDAR and the reference MM01's anemometry, and between the SoDAR and the LiDAR reference. It is defined as a short test campaign against IEC and MEASNET certified and calibrated reference instrumentation, providing quantitative traceability of performance to international standards. This specific cross-validation test cycle includes also the correlation analysis to a Windcube V2. LiDAR that is collocated at the measurement test bench.

IEC 61400-12-1 is the definitive industry-wide standard for high-quality wind measurement campaigns and the next edition (#2, currently FDIS) specifies a detailed procedure that ensures the traceability of SODAR measurements and evaluates associated uncertainty components, which can be applied in wind resource assessments. The results shown the two remote sensors uncertainty values are within the uncertainty of the mast-mounted reference anemometers.

The linear regression between SODAR and the reference anemometer measurements, as well as the SoDAR and the reference LiDAR, evaluates the systematic uncertainties in the SODAR measurements for each 0.5 m/s wind speed bin from 4-12 m/s. Wind direction measurements are also verified by means of regression analysis between SODAR and met mast wind vane and LiDAR directional measurements.

In addition, Ecofys WTTs also validated the performance of the SODAR based on the acceptance thresholds of the EU-project NORSEWI_{ND} and against Ecofys WTTs's acceptance thresholds for SoDAR field measurements.

The results of the cross-validation of the SoDAR against the met mast and the LiDAR show excellent agreement between the Lidar and SoDAR. The Met Mast correlation provides an analysis of the spatial variation one may find using a SoDAR at some distance from a reference met mast. The complete validation results from each SoDAR in correlation with the IEC-compliant MM01 measurements and the LiDAR measurements concurring with 4 measurement heights are presented. We provide a description of the testing procedures, source data preparation, filtering and criteria. The performance results are presented on the basis of 10-minute mean values of the measured quantities, including:

- Sufficient parallel data acquisition at multiple heights and in a SoDAR location near the mast MM01 (on-going location for SoDAR measurements, SoDAR Test Pad #2 (STP02)).
- Validation of wind speed at 4 measurement heights against Met Mast MM01, and validation of wind speed at 4 measurement heights against the Windcube LiDAR. Both tests include statistical analysis based on IEC 61400-12-1 (ed. 2 – FDIS) standard:
 - Wind speed correlation coefficient and regression analysis
 - Wind direction correlation coefficient
 - Uncertainty of the SoDAR wind speed measurements, per wind speed bin
- Validation of wind direction measurements at two measurement heights against Met Mast MM01.
- Validation of wind direction measurements at two measurement heights against LiDAR.
- Validation based on the acceptance thresholds of NORSEWInD criteria and against Ecofys WTTS's acceptance thresholds for SoDAR field measurements.

This study is the first cross-validation completed using the most widely used wind measurement equipment. The cross-validation result provides the industry with a better understanding of the performance of these instruments in hybrid wind resource applications.

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