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Independent Performance Verification of a Fulcrum3D SODAR at Zaragoza

Fulcrum3D Pty Ltd

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Project name:	Fulcrum3D	DNV GL / GL Garrad Hassan Deutschland GmbH Section Offshore Germany Brooktorkai 18 20457 Hamburg Germany Tel: +49 40 36149 2748 DE 118 606 038
Report title:	Independent Performance Verification of a Fulcrum3D SODAR at Zaragoza	
Customer:	Fulcrum3D Pty Ltd, Level 11, 75 Miller Street North Sydney NSW 2060 Australia	
Contact person:	Hugh Sangster	
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Task and objective:

Report of an performance verification of a Fulcrum3D SODAR at Zaragoza

Prepared by:	Verified by:	Approved by:
Patrick Schwenk Project Engineer	Andreas Beeken Project Engineer	Peter Frohböse Head of Section Offshore

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1 INTRODUCTION

GL Garrad Hassan Deutschland GmbH (member of DNV GL – hereinafter referred to as "GH-D") has been assigned on 2015-02-17 by Fulcrum3D Pty Ltd (F3D) to prepare an official independent report of an Fulcrum3D FS1 SoDAR (FS1) performance verification. In this analysis and report the FS1 SoDAR with the serial number FS1M_1012 will be treated. The verification measurements for this device were performed by F3D at the test site in Zaragoza, Spain between 2014-11-19 and 2015-01-04.

The objective of this report is to document comprehensively the Performance Verification (PV) of this SoDAR unit, independently. As such it is an independently review of the Performance Verification of an individual SoDAR unit with the goal to give an informative indication of the quality of wind data to be expected from this SoDAR unit.

The site for the validation test is located in north-east Spain, 430 m above sea level. The SoDAR validation is done versus a "classically" equipped meteorological mast (met mast). The site and in particular the met mast setup had independently been assessed in a desktop study by GH-D for its compliance to suitable standards (like IEC, see [1, 2]) and is evaluated as being concordant, see chapter 3 for more details.

This independent analysis of an FS1 SoDAR is performed according to the SoDAR PV process [3] as developed by GH-D.

GH-D has a wide range of experience in validation and testing of SoDAR remote sensing devices not least by participating in the EU-FP7 Project NORSEWInD [4].

GH-D is accredited according to ISO 17025 for measurements on wind turbines and for wind resource measurements and energy assessments. GH-D is also a full member of the network of measurement institutes in Europe 'MEASNET' and in the FGW (Fördergesellschaft Windenergie und anderer Erneuerbaren Energien). The work has been conducted in compliance with all relevant health and safety legislation. GH-D operates an Occupational Health and Safety Management System certified according to the OHSAS 18001:2007.

For confidentiality reasons the core content of the original Sodar Verification Report has been removed for this online report.

Table 1-1: List KPIs and ACs relevant for System and Data Availability

KPI	Definition / Rationale	Acceptance Criteria across total of four (4) weeks data
OSA_{CA}	**Overall System Availability – Campaign Average** .	≥95%
$OPDA_{CA}$	**Overall Post-processed Data Availability**	≥85%

Table 1-2: List of KPIs and ACs relevant for Wind Data Accuracy

KPI	Definition / Rationale	Acceptance Criteria	
		RS Best Practice	Minimum
C_{mwsd}	**Campaign Mean Wind Speed – Difference**	< 1 %	< 2%
X_{mws}	**Mean Wind Speed – Slope**	0.98 – 1.02	0.97 – 1.03
R^2_{mws}	**Mean Wind Speed – Coefficient of Determination**	>0.98	>0.97
X_{mwd}	**Mean Wind Direction – Slope**	0.97 – 1.03	0.95 – 1.05
OFF_{mwd}	**Mean Wind Direction – Offset**	< 5°	< 10°
R^2_{mwd}	**Mean Wind Direction – Coefficient of Determination**	> 0.98	> 0.97

2 IMPORTANT REMARKS AND LIMITATIONS

Independently performed (or independently reviewed) Performance Verifications (PV) of individual SoDAR devices as reported on in this document present a reasonable means to assure overall system integrity of the SoDAR unit after manufacturing, and to give an informative indication of the quality of wind data produced by the SoDAR.

Any statement given in the context of system integrity and data quality related results within this report are limited to the given test site conditions, to the prevailing atmospheric conditions and to the specific SoDAR configuration as selected during the PV campaign, only.

GH-D wants to note that the representativeness of the test site (and its degree of complexity) to potential future project sites cannot be guaranteed. Furthermore GH-D wants to point out that no site visit has been taken place before the performance verification and that the evaluation of the site complexity is only based on a desktop based assessment. GH-D strongly recommends carrying out a site visit to confirm the findings of the desktop study.

It needs to be noted that both data sets – the Sodar data and the reference met mast data – have been known to the Client (manufacturer) since well before GH-D was provided with the data. In this sense the performance verification at hand cannot be seen as a so called blind test, where the reference data is not visible to the manufacturer. In this case the data was extracted in data version 3.5.1 by F3D before hand-over to GH-D. GH-D had no insight in the Sodar data before data processing by F3D according to firmware 3.5.1.

3 CONCLUSION

Concurrent FS1 SoDAR and cup anemometer wind measurements were carried out at the Zaragoza test site to verify SoDAR wind data quality against well-known high quality met mast based cup and vane anemometry. Measurement heights of 60, 80, 99 and 101 m a.g.l. were available for wind speed correlations (78 and 97 m for wind direction correlation) between a proximate met mast and an FS1 SoDAR with the serial number FS1M_1012. The duration of the validation was 46.47 days. The test period and wind data coverage is considered sufficient for the purpose of characterizing the wind data performance of the FS1 SoDAR S/N FS1M_1012 in the context of a Performance Verification.

The total system availability for the mentioned 46.47 days assessment period was 100 %. The data coverage at the most relevant SoDAR measurement levels between 60 and 100 m a.g.l. was above 85 %, except for the near 100 m levels, showing data availability of 84 %, which is slightly below the related AC. The data coverage figures are relative to the number of maximum possible ten-minute data points for the total duration of the campaign.

Wind speed (and direction) correlations were carried out for each of the wind measurement heights mentioned above. The wind speeds of both techniques at all treated heights correlated well, showing a reasonable level of scatter and a good resemblance of SoDAR wind speeds to those of cups, in terms of mean campaign WS differences, WS linear regression slopes and coefficient of determination (R^2).

In summary the following Acceptance Criteria for respective KPIs were met.

- ✓ The Acceptance Criterion for Overall System Availability (**KPI** OSA_{CA}) to be ≥95% is successfully passed.
- ✓ The Acceptance Criterion for Overall Post-processed Data Availability (**KPI** $OPDA_{CA}$) to be ⩾85% is successfully passed at almost all relevant assessment levels, except at 100 m showing a data availability slightly below requirements.
- ✓ The Acceptance Criterion for Campaign Mean Wind Speed Difference (**KPI** C_{mwsd}) is successfully passed at 60, 99 and 101 m, meeting Best Practice criterion for the WS range >=3 m/s. At 80 m C_{mwsd} results to 1.06 % which is slightly below the Best Practise but still well within the minimum criterion of 2 %.
- ✓ The Minimum Acceptance Criterion for the relative Campaign Mean Wind Speed Differences (KPI C_{mwsd} < 2 %) is successfully passed at all relevant assessment levels (see **Error! Reference source not found.**, column 8) and for both WS ranges.
- ✓ Regression slopes (**KPI** X_{mws}) between 0.98 and 1.02 (Best Practice AC) at all treated levels and for both WS ranges, meeting the Best Practice criterion.
- ✓ R^2 (**KPI** R^2_{mws}) > 0.98 at all treated levels and for both WS ranges, meeting the Best Practice criterion.
- ✓ The Acceptance Criteria for the respective Key Performance Indicators for wind direction assessment (**KPIs** for X_{mwd}, OFF_{mwd}, and R^2_{mwd}) have successfully been passed at all comparison levels, meeting Best Practice criteria.

To conclude, the Zaragoza validation campaign indicates that the Fulcrum3D SoDAR with the serial number FS1M_1012 is able to reproduce cup anemometer wind speeds and wind vane directions at a very accurate level.

GH-D considers that for little to moderately complex terrain sites data from the Fulcrum3D device may be used in a quantitative sense with reasonable error bars for the purpose of the assessment of the wind regime at a potential wind farm site given the following criteria are met:

- The long term data accuracy stability is verified by recording data for a period sufficient to obtain an adequate in-situ correlation to an onsite reference (e.g. a short met. mast)
- Such verifications against a suitable onsite reference include WS frequency distribution comparisons, even for short periods of concurrent data, yielding a reasonable resemblance.

GH-D wants to note that the representativeness of the Zaragoza test site (and its degree of complexity) to potential future project sites cannot be guaranteed.

Furthermore, care needs to be taken with respect to the formal use of SoDAR turbulence and extreme wind speed measures, not treated in this report but known to be different from classical anemometry measures.

GH-D likes to point out that good measurement and data collection practices need to be maintained for all wind speed measurements, be they SoDAR or more conventional anemometry. Therefore, special care needs to be exercised in the transportation, installation and on-going maintenance of the SoDAR as it may be exposed to a wide range of environmental conditions at different sites over time. A key element of any formal wind study is the traceability of the wind speed data uncertainty. Hence, a strict uncertainty assessment (which is not part of this report) should be employed. Furthermore it is recommended that thorough practices of documenting the salient features of SoDAR installation and maintenance are instigated from the outset.

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