AQ510

Independent Performance Verification of an AQ510 SODAR at Fimmerstad

AQ System Stockholm AB

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Report of an performance verification of an AQ510 SODAR at Fimmerstad

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Reference to part of this report which may lead to misinterpretation is not permissible.

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B	2014-11-07	Final version (electronic issue, only)	Pasch	DeSte	DeSte

1 INTRODUCTION

GL Garrad Hassan Deutschland GmbH (member of DNV GL – hereinafter referred to as "GH-D") has been assigned on 2014-07-02 by AQ System Stockholm AB (AQS) to prepare an official independent report of an AQ510 SoDAR performance verification. In this analysis and report the AQ510 SoDAR with the serial number AQ510001 will be treated. The verification measurements for this device were performed by AQS at their test site in Fimmerstad, Sweden between 2014-04-02 and 2014-05-05.

The objective of this report is to document comprehensively the Performance Verification (PPV) of this SoDAR unit, independently. As such it is an independently review of the Performance Verification of an individual SoDAR unit with the goal (a) to assure the overall system integrity after manufacturing and prior to delivery, and (b) to give an informative indication of the quality of wind data to be expected from this SoDAR unit.

Furthermore, a PPV is not meant to replace the requirement for an on-site verification of a SoDAR in real field campaigns, typically performed in close proximity to an on-site mast over a reasonable period. This is particularly important for sites in non-benign conditions and for certain atmospheric conditions where SoDAR performance may vary from site to site.

The site for the validation test is a disused air field in Southern Sweden. 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 by GH-D for its compliance to suitable standards (like IEC, see [4, 5]) on 2013-04-17, see [1]. In comparison to the instrumentation given in [1] the mast has experienced some modifications. The two wind vanes originally installed at 59.1 and 79.1 m (both at 317°) have been shifted to 54.1 and 74.1 m respectively (both at 137°). In return 2 additional Cup anemometer have been installed at 59.1 and 79.1 m (both at 137°). GH-D recommends to perform a second assessment to proof whether the mast is still IEC compliant after modification.

This independent analysis of an AQ510 SoDAR Performance Verification (PPV) is performed according to Fimmerstad specific SoDAR PPV process [2] as developed by GH-D for AQS.

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 [7].

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.

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%
MV	Number of Maintenance Visits	N/A
UO	Number of Unscheduled Outages	N/A
CU	Uptime of Communication System	N/A

Table 3: List KPIs and ACs relevant for System and Data Availability

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	>0.97	>0.93
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	> 0.97	> 0.95
FD_{WS}	Frequency Distribution of Wind Speed	N/A	N/A
X_{TI}	Turbulence Intensity – Slope	N/A	N/A
R^2_{TI}	Turbulence Intensity – Correlation Co-efficient	N/A	N/A
A	Wind Speed Shear	N/A	N/A

Table 4: List of KPIs and ACs relevant for Wind Data Accuracy

5 IMPORTANT REMARKS AND LIMITATIONS

Independently performed (or independently reviewed) Performance Verifications (PPV) 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 of 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 PPV campaign, only.

A PPV is not thought to replace the requirement for an on-site verification of a SoDAR in real field campaigns, typically performed in close proximity to an on-site mast over a reasonable period. This is particularly important for sites in non-benign conditions and for certain atmospheric conditions where SoDAR performance may vary from site to site.

PPVs will not automatically warrant quantitative use of AQ510 data in a formal energy assessment of a prospected site. They may help reduce uncertainties and are a good step forward to help build a body of evidence.

6 CONCLUSION

Concurrent AQ510 SoDAR and cup anemometer wind measurements were carried out at the AQS Fimmerstad test site to verify SoDAR wind data quality against well-known high quality mast based cup and vane anemometry. Measurement heights of 60 m, 80 m, 100.9 m a.g.l. were available for wind speed correlations (55, 75 and 97 m for wind direction correlation) between a proximate met mast and an AQ510 SoDAR with the serial number AQ510001. The duration of the validation was 33 days. While additional measurements – in particular for higher wind speeds – would have enabled a more extensive assessment of the SoDAR system, the test period and wind data coverage is considered sufficient for the purpose of characterizing the wind data performance of the AQ510 SoDAR S/N AQ510001 in the context of a Performance Verification.

The total system availability for the mentioned 33 days assessment period was 99.2 %. The data coverage at the selected SoDAR measurement levels 60 m, 80 m, 100 m was above 90 %. 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 three (3) 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 and WS linear regression slopes.

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 all relevant assessment levels.
- ✓ The Acceptance Criterion for Campaign Mean Wind Speed Difference (**KPI** C_{mwsd}) is successfully passed at all relevant assessment levels, meeting Best Practice criterion at 100, 80 m and 60 m.
- ✓ Regression slope (**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}) > 0.97 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 Fimmerstad/Throckmorton validation campaign indicates that the AQ510 SoDAR with the serial number AQ510001 is able to reproduce cup anemometer wind speeds and wind vane directions at a reasonably accurate level.

GH-D considers that for relatively simple terrain sites data from the AQ510 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.

However, depending on the specific characteristics of the wind farm site under evaluation, there may be concerns that this PPV – as performed in relatively simple terrain – may not be representative of what may be expected at potential wind farm site. In such situations the AQ510 data recorded at a site would be used in a qualitative sense only but may well still add value to an analysis.

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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