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How to conduct a dual scanning lidar campaign: Recommendations towards a standardised workflow

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Abstract

Dual scanning lidars (DSLs) are being increasingly used for the offshore wind resource assessment (WRA) application, however the technology is yet to benefit from a global governing standard or recommended practice. This work provides recommendations towards a standardised workflow of offshore WRAs conducted with DSLs, that can be used as a starting point for further standardisation. It includes information on all stages of a project, from feasibility analysis, campaign design and installation to calibration, verification, and the measurement campaign itself.

Introduction

DSLs have become a popular choice for the offshore WRA application due to their high precision, ease of installation with minimal environmental impact and cost effectiveness. They measure the wind speed along the beam and, if the two scanning lidar (SL) beams intersect, the horizontal wind speed and wind direction can be determined at the point of intersection. Long range SLs can measure approximately 10km out over the sea whilst being installed on the shore.

Being a relatively new remote sensing application, few attempts have been made to describe and standardise the procedure used for conducting an offshore WRA with DSL. Drawing on practical experience from a number of campaigns completed or in progress, this work aims to propose a standardised workflow for conducting a DSL campaign for an offshore WRA, across all stages of the project from pre-assessment to data treatment.

The goal of this project is to provide a starting point for further standardisation such as the upcoming IEA task 52 recommended practice on the use of scanning lidars offshore. A complete document will be made available later in the year.

Pre-assessment

At the pre-assessment stage of your WRA project there are several aspects of DSL operation you must consider before committing to a campaign with them.

As DSL usually measure the offshore wind resource whilst being situated on the coast, ensuring that you can have suitable data availability at the range required, before investment, is key. Estimates of the range that a scanning lidar can achieve, in a given site (and therefore meteorological condition), can be obtained from different sources, listed in order of preference:

1. A simulation tool that takes into account the configuration of the scanning lidar and the local meteorological conditions.
2. Historical performance of the same model of scanning lidar with a similar configuration and in similar meteorological conditions.
3. Manufacturer estimates.

The estimate of range relative to your desired measurement location(s) gives the area of coastline, or the offshore installations, where the scanning lidars could be placed. The next stage is to consider the practical elements needed for a scanning lidar installation, detailed in section on campaign implementation. This often yields a finite list of suitable siting locations for further consideration.

To determine the optimum siting locations between the candidate sites, some consideration of measurement uncertainty depending on beam geometry must be done. In the ideal case, this is done with some comprehensive model of DSL reconstruction uncertainty which can give a quantitive estimate that can be evaluated directly. If this is not available, the following guidelines can be followed:

- Azimuth angle difference between the two beams between 30-150^{o} and optimally 90^{o}
- Elevation angles less than 5^{o} and optimally 0^{o}
- A lower range is preferable to a higher range

Pre-verification

To provide confidence in the WRA to third parties, it is common industry best practice that the measurement devices undergo a pre-validation campaign. To be consistent with procedures for “conventional” WRA campaigns with vertical profiling lidars or met masts, it is recommended that DSLs undergo the same process.

The quantities measured by the single SLs, such as radial wind speed, range and pointing angles, should be be verified against a reference, as well as the quantities relating to the DSL reconstructed quantities such as horizontal wind speed horizontal wind direction and synchronization.

These verifications can be done either at a different site to that of the operational campaign, or at the operational site if a nearby reference is available. The quality of the reference should meet the appropriate standards described in the IEC 61400-12-1.

Campaign implementation

When considering installation sites for the SLs, a reliable power supply and good internet connection are essential. It must also be ensured that the line of site to the target measurement locations are not obscured at any time, even transiently by e.g., moving tree branches or passing cars.

Maintaining a good pointing accuracy is essential. It is therefore necessary that the SL be installed on a hard surface that will not move over the course of the campaign and should not be restrained under tension. The amplitude of the pitch and roll of the SL can be preliminarily minimized using the in-built, or an external inclinometer. It is also essential to perform, and document, a pointing accuracy calibration. A hard target calibration is the conventional way to do this when suitable hard targets such as wind turbines, masts or buildings are available with a clear line of site to the SL. Calibrations using drones and sea surface levelling present valid alternatives when suitable hard targets are not available. The pointing accuracy calibration for both azimuth and elevation angle should be done at at least three azimuths giving the azimuthal variation of pointing error.

A series of fixed scans should be used, with the angle from the scanning head of the lidar to the target position and altitude calculated theoretically, taking into account the curvature of the earth. The angles should be precisely corrected using the results of the pointing calibrations. Multiple heights at the same location can be configured to allow the measurement of shear.

To deal with the large volumes of data that DSL can produce, it is recommended to set up automatic data extraction from the lidar. If the data needs to be transferred, an FTP server is a reliable way to do so.

Campaign operation

Technical unavailability of either of the SL will interrupt the measurements of a DSL campaign and therefore maximising system uptime is important. For this, information such as component status, disk occupation, power supply and synchronisation should be regularly, and preferably automatically, monitored.

Device component failures should be fixed as quick as possible, for example by local service partners of the lidar manufacturer. If this is not possible, it may be advantageous to store spare parts close to the site to reduce measurement downtime.

To allow for monitoring of DSL reconstructed quantities, notably combined data availability, it is recommended to have an automatic data processing pipeline to provide regular and up-to-date reconstructed data.

The pointing accuracy calibration should be repeated at the end of the campaign to provide confidence that it has not changed. Regular calibrations, for example monthly, are advised if possible.