Measurement uncertainties for Stage 3 floating lidars employing the risk-based approach to measurement campaigns

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Intro

Several floating lidar systems (FLS) have achieved The Carbon Trust Offshore Wind Accelerator (OWA) Roadmap [1] Stage 3 maturity status meaning that a unit pre-deployment verification offshore is no longer mandatory. However, these validations are used to inform the FLS measurement uncertainty in a preconstruction energy assessment. When this risk-based approach is utilized, there is a gap in the uncertainty model. This unknown may lead to inaccurate wind measurement uncertainties in a windfarm preconstruction energy assessment.

Methods

A database of verifications for the FLS model of interest is assembled and the P90 uncertainty for each wind speed bin is determined. From this database the range of environmental variables (EV) that were identified as significant independent EVs in the device-type Classification (i.e wind shear) are used to determine if the P90 is representative of the site. When the mean of each EV observed during the site measurement campaign (SMC) is between the 10^{th} and 90^{th} percentile of the EV in the envelope of operational conditions (EOC), the measurement uncertainty attributed to the floating lidar units is then the P90 uncertainty profile from the FLS model database.

An example is provided in the top figure where a comparison between the EOC (in blue) and EV measured during the SMC (in green) is shown. The red vertical line represents the mean EV value met during the SMC and is well between the P10 and P90 values from the EOC.

If the mean falls outside these bound as shown in the lower figure, then additional uncertainty (u_i) shall be calculated per IEC 50-4 [3] and are as follows:

$$u_i^2 = m_i * \varepsilon_i$$

where

m_i is the rate of change of measurement error with environmental variable i

ε_i is the amount by which environmental variable i is out of range and is expressed as,

$$\varepsilon_i = x_{\text{mean,SMC},i} - x_{\text{p10–90,EOC},i}$$

and

$x_{\text{p10–90,EOC},i}$ is the P10 or P90 value (use the nearest to $x_{\text{p10–90,EOC},i}$) of environmental variable i within the EOC

$x_{\text{mean,SMC},i}$ is the mean value of environmental variable i within the SMC.

This additional uncertainty is calculated for each EV outside to EOC and combined in quadrature with the P90 uncertainty profile defined above to obtain the final uncertainty profile.

Discussion

A pre-deployment verification can provide the measurement uncertainty of a particular FLS and has the advantage of identifying potential issues such as higher than desired measurement uncertainties, low recovery rates, or power supply inadequacies etc. before deployment. However, completing a post-deployment verification is acceptable if good consistency with SMC is ensured.

The table to the right provides a comparison of typical ranges of FLS measurement uncertainty. Though it is more cost-effective to deploy a Stage 3 FLS without an offshore verification, there is a trade-off of a potential increase in the device measurement uncertainty. DNV estimates the increase in device measurement uncertainty when there is no verification campaign to be approximately 0.5 % to 1.0 %.

A **Stage 3 FLS may skip a deployment verification**. As a result, the FLS measurement uncertainty is **unknown**.

DNV recommends **using the P90 measurement uncertainty** from a **FLS device-type** verification database considering the envelope of operational conditions between the database and site measurement campaign.

Typical FLS measurement uncertainties for different FLS scenarios

OWA Roadmap FLS Stage [1]	Offshore Verification	Measurement Uncertainty [%]	Comment about site measurement campaign (SCM)
Pre-commercial (Stage 2)	yes	3.2 – 4.5	Assumes no device-type Classification
	no	N/A	Shall not be used for formal SMC
Commercial (Stage 3)	yes	2.0 – 3.5	Metocean conditions are within the EOC during the SCM
	no	2.5 – 4.0	

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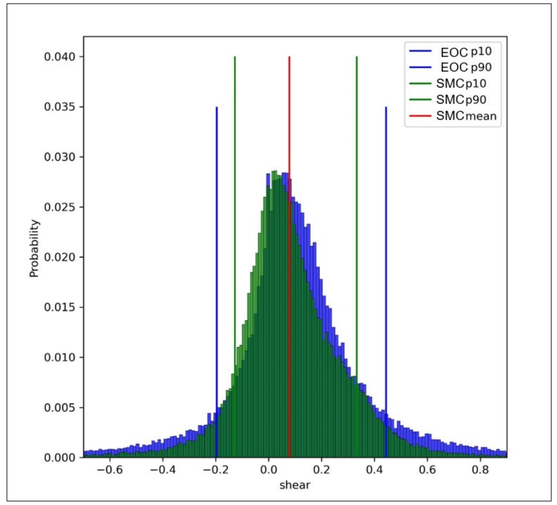
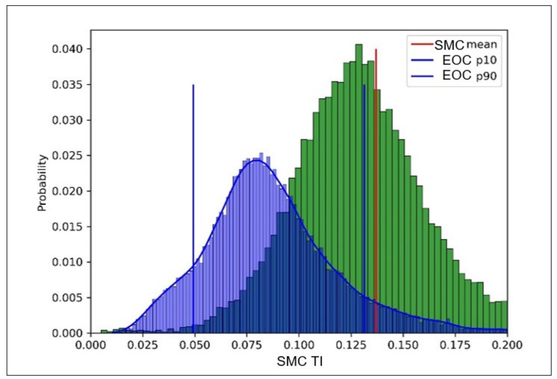


SMC site conditions are within the EOC



SMC site conditions are outside the EOC

References:

[1] Carbon Trust "Carbon Trust Offshore Wind Accelerator Roadmap for the Commercial Acceptance of Floating LiDAR Technology – Version 2.0". 2018.

[2] International standard IEA Wind, "RP 18. Floating Lidar Systems". 2017.

[3] International standard IEC TS 61400-50-4, "Wind energy generation systems – Part 50-4: Use of floating lidars for wind measurements". 2024.

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