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Leveraging Scanning LiDAR offshore how Europe can learn from Japan

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Abstract

In this study the results of several accuracy verifications of Scanning LiDAR(SL) measurements in offshore were reported. At first, we confirm the accuracy in Single scanning LiDAR(SSL) is almost same to cup anemometer. Next, when verifying DSL accuracy, it was confirmed that the observation results satisfied the KPI described in the NEDO Guidebook(ref:1) Therefore, it was confirmed that the DSL in this case can be considered as having the same accuracy as a cup anemometer. The simulated effect of measuring multiple Virtual Met Masts(VMMs) using Dual SL(DSL) was also explored.

Introduction

In Japan, offshore wind energy is growing, with the Japanese government confirming targets of eliminating greenhouse gas emissions by 2050 and increasing offshore wind farm capacity to 10GW capacity by 2030.Traditionally, the most accurate and reliable measurement approach is the offshore met mast however they come with a huge cost and lengthy permission application processes. Another approach is Light detecting and Ranging (LiDAR) technology. In the Japanese market, near-shore projects are dominate and this means that scanning LiDAR (SL) is an attractive measurement technology as it can measure the offshore wind from the coast. In Mar 2022, New Energy and Industrial Technology Development Organization (NEDO), a national research and development agency, published an interim report of their Offshore Wind Observation Guidebook (NEDO Guidebook). Various recommendations of how to use and verify the accuracy of SSL and DSL are included. In this work, the results of accuracy verifications conducted by GPI are presented, for both SSL and DSL. In addition, the effect of measuring multiple Virtual Met Masts(VMMs) with DSL is explored. All these verifications are compared to performance KPIs from the NEDO Guidebook.

Methods

For the verification of SSL accuracy, Vaisala's Windcube Scan 200S and 400S models were used. The measurement principle uses plan position indicator (PPI) scans with a fixed elevation angle and varying azimuth angle. The horizontal wind speed and direction is obtained through an iterative fitting of the relationship between the radial wind speed and the azimuth angle across the PPI scan. This produces a “virtual anemometer” at the center of scanned sector, which is compared with a cup anemometer attached to a met mast in order to verify the accuracy of the SSL measurement. This accuracy verification was conducted at several sites.

DSL observations were done with two of Vaisala’s Windcube Scan 400s. A beam intersect method was used where the radial wind speeds of each SL were used to reconstruct the horizontal wind speed and direction at the intersection point. Multiple of these “virtual anemometers” can be measured simultaneously over a 10-minute period and are arranged in a vertical profile to form a “virtual met mast” (VMM), as in Figure 1.

If DSL could measure multiple virtual met masts simultaneously over a 10 minute period this would be a major advantage (see Figure 2). To test this, the DSL dataset that measured a single VMM was split into several parts, to artificially increase the time between each full tour of the measurement points and simulate the presence of more VMMs.

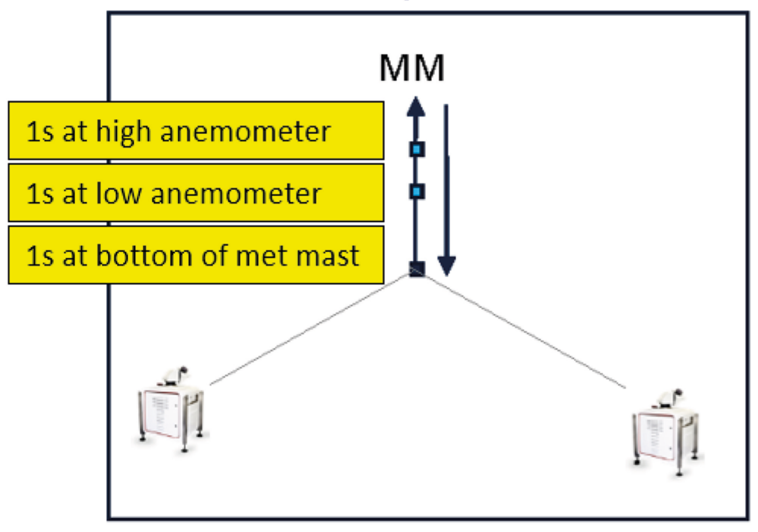

Figure 1 DSL measurement schematic (2 measurement heights)

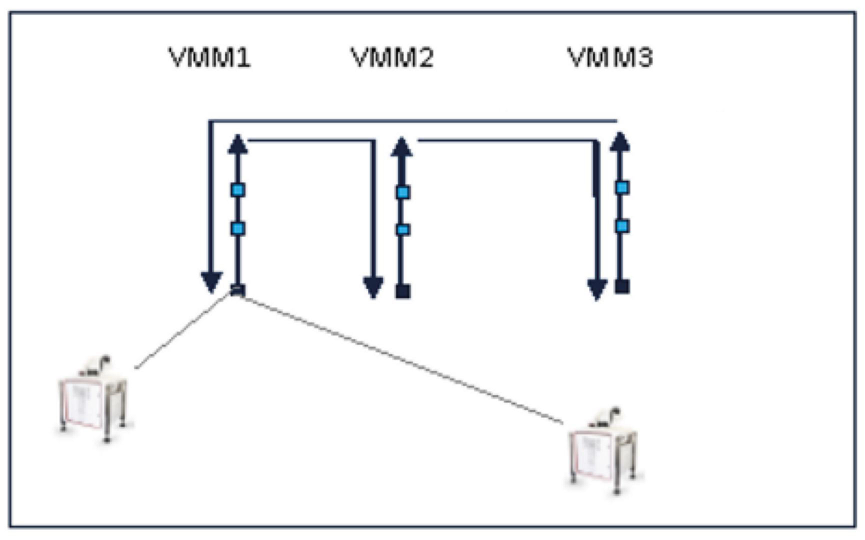

Figure2 Conceptual diagram of multiple virtual met masts measured by DSL

Results

Table 1 shows the accuracy verification results of the SSL across multiple sites. The mean coefficient of determination was 0.97 and the mean measurement error was -1.1%. It was confirmed that the average wind speed can be measured with almost the same accuracy as with cup anemometers in some cases. Considering these results, it is necessary to set a standard practice of how to use SSL for wind resource assessment from the view of minimizing risk and uncertainty.

Table 1 Accuracy verification examples of SSL (5 cases) * In all cases, the observation period is one month or more.

Windcube Scan model	Coefficient of Determination	Measurement error [%]
200S	0.96	0.3
200S	0.98	-2.0
400S	0.97	-2.0
400S	0.97	-2.0
400S	0.98	0.0

For DSL, NEDO guidebook provides a key performance indicator (KPI) that must achieved in order to pass verification, shown in Table 2. The results of the DSL accuracy verification are shown below in Figure 3.

Table 2 KPI and verification results related to DSL accuracy verification

Evaluation target	KPI	outcome
wind velocity	Regression slope Minimum: 0.97~1.03 Best practice: 0.98~1.02	0.98
	Coefficient of determination Minimum: >=0.97 Best practice: >=0.98	0.99
Wind direction	Regression slope Minimum: 0.95~1.05 Best practic: 0.97~1.03	0.99
	Regression intercept Minimum: <10 degrees Best practice: <5 degrees	-4.4
	Coefficient of determination Minimum: >=0.95 Best practice: >=0.97	1
Standard deviation of wind speed	Mean error within 5%	4.50%

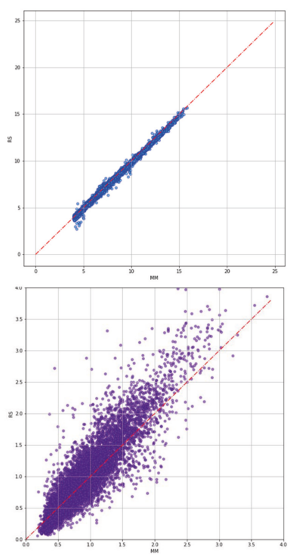

Figure3.Blue:Scatter plot of wind speed,Green:Scatter plot of wind direction,Purple:Scatter plot of wind speed standard deviation,x axis is cup anemometer, y axis is virtual anemometer(DSL)

The accuracy compared to the cup anemometer of the DSL datasets that were split to artificially simulate more virtual met masts are shown in Table 3, along with NEDO’s KPI for each quantity. In every case, with the data being split up to 4 times and each meeting NEDO’s KPIs.

Table3. Accuracy of split DSL dataset to simulate more VMMs(4VMM case)

Number of divisions	wind velocity		Standard deviation of wind speed
	Regression slope	Coefficient of determination	Mean error within 5%
	Minimum: 0.97~1.03 Best practice: 0.98~1.02	Minimum: >=0.97 Best practice: >=0.98	
2	0.985	0.993	4.10%
	0.984	0.993	4.30%
3	0.985	0.993	4.20%
	0.985	0.993	4.60%
	0.984	0.993	4.20%
4	0.985	0.992	4.40%
	0.984	0.992	4.40%
	0.985	0.992	4.50%
	0.985	0.992	4.60%

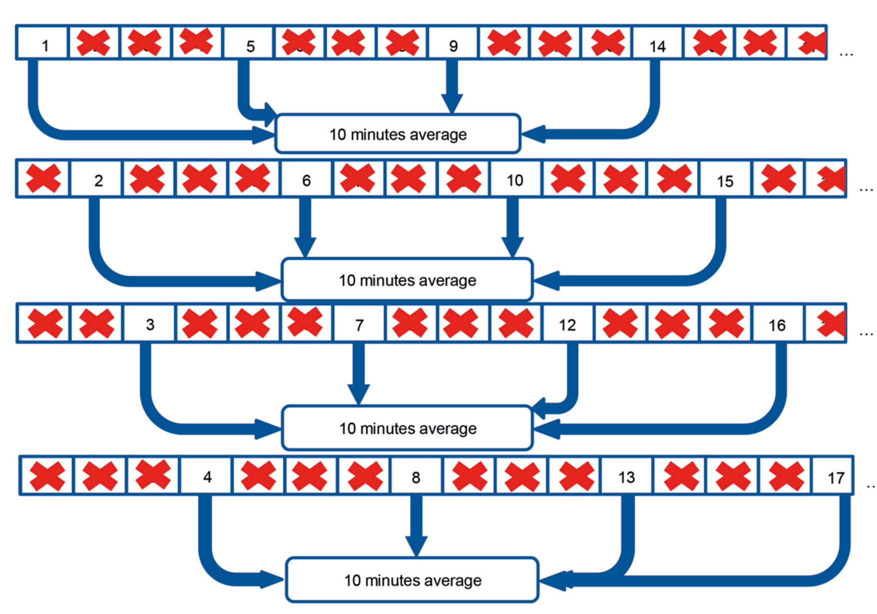

Figure4. method of data division to simulate multiple virtual met masts -methodology

Conclusions

In this study, SSL was found to have suitable accuracy on wind speed. Next, when verifying DSL accuracy, it was confirmed that the observation results satisfied the KPI described in the NEDO Guidebook. Therefore, it was confirmed that the DSL in this case can be considered as having the same accuracy as a cup anemometer. Finally, when the accuracy of measuring multiple VMMs using DSL was studied, it was found that when measuring up to 4 VMMs, the results cleared the KPIs described in the NEDO Guidebook. This means that even when multiple VMMs are being measured by DSL, the average wind speed can be measured with almost the same accuracy as a cup anemometer. This prevents the need for multiple pairs of DSLs being used to measure different locations.

References

1. New Energy and Industrial Technology Development Organization(NEDO),Guidebook about offshore measurement, March 2022