Floating LIDAR is a solution to reduce the cost of the offshore wind measurement. The correction of the error of the measured wind speed induced by the motion of the floating LIDAR is needed. Although several studies have been carried out in the correction of the floating LIDAR measurement [1][2], the detailed correction algorithm and their accuracy were not made clear. In this study, a correction method for the error in lidar measurement induced by the floater motion was proposed, and numerical verification and validation by the measurement in Fukushima project is carried out.

**Fukushima Project**

In this project, one floating power sub-station was installed off the coast of Fukushima. A met mast is installed on this floater and wind speed are measured by using cup and sonic anemometers as well as floater motion by using RTK-GPS, accelerometer and gyro. A lidar is also installed at the helicopter deck.

**Principles of the LIDAR measurement system**

In this study, Wind cube V2 Offshore was used which irradiates beams into 5 different directions; upwards, north, south, east and west, and there is a $\theta_0$ degree irradiation angle for all the cardinal beams and about 1 second accumulation time per beam. Wind speeds in the line of sight (LoS) of the laser beam are measured.

**Wind speed calculation on fixed lidar**

X-axis horizontal wind speed $u$ and vertical wind speed $w$ were calculated as follows. In this method wind field is steady in time between 1st LoS irradiation time to 5th LoS irradiation time.

$$u = \frac{V_1 - V_2}{2 \sin \theta_0}$$

$$w = \frac{V_1 + V_2 + V_3}{4 \cos \theta_0}$$

In Windcube V2 Offshore, $\theta_0 = 28^\circ$.

**Correction of tilting**

1) Horizontal wind speed component in $p_2-p_4$ plane ($u_{24}$) and $p_1-p_3$ plane ($u_{13}$) at the target height is calculated respectively.

2) Horizontal wind speed component ($u_{13}$) and direction ($\psi_{13}$) at the target height is calculated.

3) Vertical wind speed component ($w$) is calculated.

**Horizontal wind speed component in $p_2-p_4$ and $p_1-p_3$ plane**

Define the angle between LoS and horizontal ground ($\psi_3$) as:

$$\psi_3 = 90^\circ - \theta_3 - \beta$$

where $\beta$ is the pitch angle of the lidar.

The wind speed component in LoS ($V_x, V_y$) can be written as:

$$V_x = u_{24} \cos \psi_3 + w_{24} \sin \psi_3$$

$$V_y = u_{24} \sin \psi_3 + w_{24} \cos \psi_3$$

where, $w_{24}$ is the component of the wind speed in p2-p4 plane and perpendicular to $u_{24}$.

By solving this equation, $u_{24}$ and $w_{24}$ can be calculated. ($u_{13}$) can also be calculated in the same way.

**Horizontal wind speed and direction**

Let the direction of $u_{24}$ and $u_{24}$, $u_{13}$ and $u_{13}$ respectively. They can be written as:

$$u_{24} = u_{13} + p_3 - p_4$$

$$u_{13} = u_{13} + p_3 - p_4$$

The horizontal wind direction $u/|u|$ and speed $|u|$ can be calculated as:

$$\frac{u}{|u|} = \begin{bmatrix} \cos \psi_u & -\sin \psi_u \\ \sin \psi_u & \cos \psi_u \end{bmatrix} \begin{bmatrix} u_{24} \\ w_{24} \end{bmatrix}$$

where

$$\psi_u = \arctan \left( \frac{u_{24}}{w_{24}} \right)$$

**Vertical wind speed**

Vertical wind speed can be calculated as the average of vertical wind speed calculated from each LoS speeds by the equation as follows.

$$w = \frac{V_1 - V_2}{R_u}$$

where

$$u_{\text{correction}} = u - w$$

**Conclusion**

In this study, a correction method for the error in lidar measurement induced by the floater motion was proposed, and numerical verification and validation by the measurement in Fukushima project is carried out. Following results were obtained.

1. When the floater motion is large, the error in the lidar measurement is large. This error can be corrected by the proposed method.

2. Proposed method is applicable to the floater motion compensation at Fukushima substation.

**References**


**Introduction**

Correction of Motion-induced LIDAR Measurements Errors and Validation by Met Mast Measurements

Ran Wakabayashi*
Tatsunori Kawahigashi* Atsushi Yamaguchi* Takeshi Ishihara*
*Department of Civil Engineering, School of Engineering, The University of Tokyo Email: wakabayashi@bridge.t.u-tokyo.ac.jp

**Correction method**

Proposed correction method was verified by numerical simulation and validation by measurement.

**Verification by simulation**

- Three different synthetic floater motion data were generated.
- The maximum pitch and roll angle of the motion data are 5, 15 and 30 degree.
- 10 minutes average wind speed in three component are verified.

**Verification by met mast**

The lidar measured wind speed at Fukushima substation was compared based on the proposed method and validated by the cup anemometer measurement.

- The tilt angle of the floater is relatively small and the error induced by the tilt of the floater is small.
- The proposed method can be validated.

**Conclusion**

In this study, a correction method for the error in lidar measurement induced by the floater motion was proposed, and numerical verification and validation by the measurement in Fukushima project is carried out. Following results were obtained.

1. When the floater motion is large, the error in the lidar measurement is large. This error can be corrected by the proposed method.

2. Proposed method is applicable to the floater motion compensation at Fukushima substation.