An Experimental Study on the Effects of Base Motion on the Aeromechanic Performance of Floating Wind Turbines

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Abstract. An experimental study was conducted to investigate the effects of the wave-induced base motions experienced by floating wind turbines sited in offshore wind farms on their aeromechanic performance and wake characteristics, in comparison with those of a bottom-fixed wind turbine. The experimental study was performed in a large-scale atmospheric boundary layer (ABL) wind tunnel with a scaled wind turbine model placed in a turbulent boundary layer flow with similar mean and turbulence characteristics as those over a typical offshore wind farm. During the experiments, a scaled wind turbine model was mounted on a translational and rotational stage, which can generate translation and/or rotation motions to simulate the dynamic wave-induced motions (i.e., surge, pitch and heave motions) experienced by floating wind turbines in offshore wind farms. In addition to measuring dynamic wind loadings (both forces and moments)acting on the model turbine, a high-resolution Particle Image Velocity (PIV) system was also used to conduct detailed flow field measurements to characterize the turbine wakes with the turbine base in motion. The detailed flow field measurements were correlated with the dynamic wind load data to elucidate underlying physics for higher total power yield and better durability of floating offshore wind turbines.

1. Introduction

Offshore wind energy is one of the most abundant and promising renewable energy sources. The United States is especially fortunate to be surrounded by vast waters on both sides of the nation. This provides a unique opportunity for offshore wind farm developments in USA. There is over 4000 GW of wind potential within 50 nautical miles of the U.S. coastlines [1], which is approximately four times the current U.S. power generation capacity. Offshore wind energy is usually divided into three categories, depending on the depth of water where the turbines to be installed, i.e., shallow water zone, intermediate water zone, and deep water zone. The depth of the water dictates the type of substructure technology needed to install offshore wind turbines. In shallow waters (i.e., 0 m to 30 m), the turbines are usually fixed to the sea floor by means of a monopile or gravity based foundations. In intermediate waters (i.e., 30m to 60 m), the wind turbines are also being fixed to the sea floor, but by different kind of substructures such as jacket or tripods. As the water depth increases beyond 60m, the cost of substructure increases substantially, making it almost economically infeasible to fix the turbines to the sea floor. Therefore, the wind turbines will need to be floated in deep waters.

By the end of 2013, there were 69 offshore wind farms operating in 11 European countries, yielding over 6.5 GW of electricity. All of these wind farms are located in shallow waters with depths less than 20 meters where the turbines are fixed to the sea floor [2]. Unlike the shallow European waters, the U.S. waters are, on the other hand, mostly deep (with the exception of a few regions in the East Coast and the Gulf of Mexico). Therefore, offshore wind farm development in the U.S. will most
likely be based on the floating concept. The floating platforms that have been proposed for wind turbine applications include; semi-submersible, tension leg platform, and spar buoy.

Regardless of the platform type, floating platforms cannot easily provide high degrees of stability for mounting wind turbines. This is especially true for the Horizontal Axis Wind Turbines (HAWTs) since their centers of gravity (C.G.) are located at a much higher locations in relation to their Centers of Buoyancy (C.B.), therefore, creating an unstable floating structure. There are six degrees of freedom (6-DOF) associated with any floating structures, three displacements (surge, sway, and heave) and three rotations (roll, pitch, and yaw). The dynamic excitation of wind and waves, will induce excessive motions along each of the 6-DOF’s of the floating platform. These motions will then be transferred to the wind turbine itself, and directly impact the power production performance and dynamic wind loadings acting on the wind turbine.

It is well known that offshore environments are characterized by stronger wind speeds (due to shallower boundary layer profiles), and lower turbulence intensities (due to the smoother surface roughness of offshore environments). Generally, the higher and steadier wind speeds over offshore wind farms would result in higher energy production of wind turbines. The reduced ambient turbulence of offshore environment would also be beneficial to reduce the fatigue loads acting on wind turbine components. However, the reduced ambient turbulence levels may also result in reducing the entrainment of the high momentum flow from above or surrounding undisturbed flows to re-charge the low momentum turbine wake flow, thereby, causing the low-speed turbine wake to travel a longer distance. Hence, the spacing between the offshore wind turbines may need to be larger, in comparison to that of onshore wind turbines. On the other hand, the effects of the base motion on a floating offshore wind turbine can be considered as a stationary wind turbine operating in a highly unsteady flow. It is anticipated that the base motions of the floating wind turbine would have a significant influence on the turbulent mixing process in the turbine wake flow, thereby, impacting the recovery of the low momentum wake flow behind the floating wind turbine. As a result, it may affect the distance required between the offshore floating wind turbines in an offshore wind farm.

In comparison with the extensive studies on the aerodynamics of bottom-fixed wind turbines, only very few can be found in the literature to investigate the effects of the wave-induced base motions on the aeromechanic performance and wake characteristic of floating wind turbines sited in offshore wind farms. Rockel et al.[3] performed a wind tunnel study to investigate the influence of the platform pitch motion on the wake characteristics of a floating wind turbine. They found that the platform pitch would create an upward shift in all components of the turbine wake flow and their fluctuations. They also suggested that the vertical flow created by the pitch motion as well as the reduced entrainment of the kinetic energy from undisturbed flow above the turbine would result in potentially higher wind loads and less kinetic energy available for a downwind turbine. Sebastian and Lackner [4] performed a series of numerical simulations to study the unsteady aerodynamics of offshore floating wind turbines. They found that offshore floating wind turbines are subjected to significant aerodynamic unsteadiness, in comparison with fixed-bottom wind turbines. The strong base motions of a floating wind turbine may even cause the turbine operation changing from a windmill state to a propeller state. They also suggested that many conventional wind turbine aerodynamic analysis methods may not be applicable to the highly dynamic environment in which floating wind turbines are expected to operate.

In the present study, we reported a wind tunnel study to investigate the effects of the wave-induced base motions experienced by floating offshore wind turbines on their aeromechanics performance and wake characteristics, in comparison with those of conventional bottom-fixed wind turbines. The experimental study was performed in a large-scale atmospheric boundary layer (ABL) wind tunnel with a scaled horizontal-axis wind turbine (HAWT) model placed in a turbulent boundary layer flow with similar mean and turbulence characteristics as those over a typical offshore wind farm. The turbine model was mounted on a translational and rotational stage, which can be used to generate translational and rotational motions to simulate the wave-induced motions (i.e., surge, pitch and heave motions) experienced by floating wind turbines in deep waters. During the experiments, a highly
sensitive force/moment transducer was mounted at the base of the model turbine to measure the
dynamic wind loading acting on the turbine model for the test cases with and without base motions. In
additional to using a cobra anemometer probe to measure flow velocity at the pointes of interest, a
high-resolution digital particle image velocimetry (PIV) system was also used to achieve detailed flow
field measurements to quantify the flow characteristics in the near wake behind the turbine model.
The detailed flow field measurements were correlated with the dynamic wind loading data to elucidate
underlying physics for higher total power yield and better durability of floating offshore wind turbines
sited in deep waters.

2. Test Turbine Model and Experimental Setup

The experimental study was performed in the large-scale Aerodynamic/Atmospheric Boundary
Layer (AABL) wind tunnel located in the Department of Aerospace Engineering at Iowa State
University. The AABL wind tunnel is a closed-circuit wind tunnel with a boundary-layer test section
20 m long, 2.4 m wide and 2.3 m high, optically transparent side walls, and with a capacity of
generating a maximum wind speed of 40 m/s in the test section. Arrays of chains were laid-out on the
wind tunnel’s floor on the upstream of the wind turbine model in order to generate
turbulent boundary layer flow with similar mean and turbulence characteristics as those over typical offshore
wind farms.

As described in Zhou & Kareem (2002), the velocity profile of a typical ABL wind over a wind
farm can be expressed by using a power function, i.e.,

\[ U(z) = U_H \left( \frac{z}{H} \right)^\alpha \]

where \( U_H \) is the wind speed at a reference height of \( H \) (i.e., turbine hub height for the
present study). The power

law exponent \( \alpha \) is a function of the terrain roughness. Figure 1 gives
the measured velocity and turbulence intensity
profiles of the incoming boundary layer airflow in
the test section of the
AABL tunnel used for the present study. The measured mean velocity data were found to be fitted
well with a power function with the power law exponent \( \alpha \approx 0.11 \), which agrees well with the ISO
standard for offshore ABL wind profile (i.e., \( \alpha \approx 1/8.4 \)). The measured turbulence intensity of the
incoming airflow at the turbine hub height was found to be about 10%, which agrees with the field
measurement data reported in Hansen et al. (2012) for the wind turbines in Horns Rev offshore wind
farm. For comparison, Tong [7] suggested that the typical turbulence intensity levels for offshore wind
turbines would be about 8%.

A scaled horizontal axis wind turbine (HAWT) model with a hub height of \( H=270 \) mm and rotor
diameter of \( D =300 \) mm, which was manufactured by using a rapid prototyping machine (i.e., 3-D
printer), was used for the present experimental study. The rotor blades were designed based on the
ERS-100 prototype turbine blades developed by TPI Composites, Inc. As shown schematically in Fig.
2, The rotor blade has a constant circular cross section from the blade root to 5% blade radius (R), and
three NREL airfoil profiles (S819, S820, S821) are used at different spanwise locations along the rotor

![Fig. 1: Flow characteristics of the incoming boundary layer airflow used for the present study. (a) Mean streamwise velocity profile; (b) Turbulence intensity profile.](image)
blade. The S821 airfoil profile is used between 0.208R and 0.40R, the S819 primary airfoil is positioned at 0.70R, and the S820 airfoil profile is specified at 0.95R. Further detailed information about the design parameters and manufacture of the HAWT model is available in Yuan et al. (2014) and Tian et al. (2015).

In the present study, the incoming airflow velocity at the turbine hub height was maintained at $U_H = 3.5\text{m/s}$. The corresponding chord Reynolds number of the model turbines (i.e., based on the wind speed at the turbine hub height and averaged chord length of the main rotor blades) was found to be about 6,000, which is much lower than those of the utility-scale turbines (i.e., $Re_C > 1.0\times10^6$). As described in Alfredsson et al. (1982), while the working Reynolds number of a turbine may affect its power production performance, the flow characteristics in turbine wakes would become almost independent of Reynolds numbers when the Reynolds numbers becoming high enough. More recently, Chamorro et al. (2012) suggested to use the Reynolds number, $Re_D$, which is defined by using the wind speed at the turbine hub ($U_H$) and turbine rotor diameter ($D$), to characterize turbine wake statistics. They found that mean velocity in a turbine wake would reach Reynolds number independence at $Re_D \approx 4.8\times10^4$ and that of higher-order flow statistics at $Re_D \approx 9.0\times10^4$. For the test cases of the present study, the Reynolds number, $Re_D$, is about 90,000, which is in the range of the required critical value to reach Reynolds number independence for turbine wake statistics as suggested in Chamorro et al. (2012).

In the present study, the kinematic similarity between the scaled model turbine used in the lab experiment and the large floating wind turbines sited in offshore wind farms was achieved by maintaining the same ratio between the velocity of the base motions to the airflow velocity at the turbine hub height for both the model and the prototype., i.e.,

\[
\left( \frac{U_{\text{base}}}{U_H} \right)_{\text{prototype}} \sim \left( \frac{U_{\text{base}}}{U_H} \right)_{\text{model}}.
\]

In the present study, the turbine base motion reported in Sebastian and Lackner [4] were selected as the wave-induced base motions for prototype floating wind turbines sited offshore wind farms.

As shown in Fig. 3, the wind turbine model, along with the JR3 load cell, was mounted on a motion simulator to generate translational and rotational motions to replicate the wave-induced motions (i.e., surge, pitch and heave motions as illustrated schematically in Fig. 4) typically experienced by floating wind turbines in deep waters. The motion simulator, which was manufactured by Newport Corporation, can be programmed to generate both translation and rotation motions to replicate the wave-induced motions (i.e., surge, pitch and heave motions) of a floating wind turbine sited in deep water. During
the experiment, the motion simulator was carefully installed under the bottom floor of the wind tunnel test section to avoid any disturbances to the incoming ABL wind due to the existence of the device. The model turbine was then placed on the top of the motion simulator through a special cut in the tunnel’s bottom floor, to prevent the air from leaking out of the tunnel.

During the experiments, a Monarch tachometer was used to measure the rotation speed of the wind turbine blades. After placed into the turbulent ABL wind shown in Fig. 1, the tip-speed-ratio (TSR) of the model turbines was found to be 4.5 (i.e., \( TSR = 4.5 \)). It should be noted that, a typical utility-scale wind turbine operating in modern wind farms usually has a tip-speed-ratio value of \( TSR \approx 4.0 \sim 8.0 \), as described in Burton et al. (2001).

A high-sensitivity load cell (JR3 load cells, model 30E12A-I40) was mounted at the bottom of the turbine tower to quantify the dynamic wind loadings acting on the turbine model. The JR3 load cell is capable of measuring instantaneous aerodynamic forces and the moments about each axis with a measurement uncertainty levels being smaller than \( \pm 0.25\% \) of the force measurement range (40N). During the experiments, the dynamic wind loadings acting on the turbine model were measured at a sampling rate of 1,000 Hz with the duration of 200 seconds for each test case.

Figure 5 illustrates the experimental setup used in the present study to quantify the flow characteristics of turbine wakes by using a high-resolution Particle Image Velocimetry (PIV) system. For the PIV measurements, a fog generator was used to generate small oil droplets of \( \sim 1 \) \( \mu \)m in size to seed the incoming boundary layer airflow. A double-pulsed Nd:YAG laser (EverGreen200, BigSky Corp.) with a pulse energy of 200 mJ/pulse at the wavelength of 532nm was used as the illumination source. A set of mirrors along with spherical and cylindrical lenses were used to shape the laser beam into a laser sheet of \( \sim 1.0 \) mm in thickness to illuminate the tracer particles seeded in the airflow. Two high-resolution digital cameras (PCO1600, CookeCorp) were used for PIV image acquisition in order to have a larger measurement window to reveal the evolution of the unsteady wake vortex structures behind the model turbines. The digital cameras and the double-pulsed Nd:YAG lasers were connected to a host...
computer via a digital delay generator (Berkeley Nucleonics, Model 565), which controlled the timing of the pulsed laser illumination and image acquisition for PIV measurements.

In order to determine the ensemble-averaged flow quantities (e.g., mean flow velocity, TKE, and Reynolds shear stress), PIV image acquisition rate was selected to a frame rate that is not a harmonic frequency of the rotation speed of the turbine rotor blades. A cross-correlation algorithm with interrogation window size of 32×32 pixels and an effective overlap rate of 50% was used for PIV image processing to derive instantaneous flow velocity vectors from the acquired PIV images. The ensemble-averaged flow characteristics in the terms of mean flow velocity, in-plane turbulence kinetic energy (i.e., \( \text{TKE} = 0.5 \times (\bar{u}^2 + \bar{v}^2)/U_m^2 \)), and normalized Reynolds shear stress (i.e., \( \tau = -u'v'/u_m^2 \)) were determined based on about 1,000 frames of instantaneous PIV measurements for each test case. For the PIV measurement results given in the present study, the measurement uncertainty level was estimated to be within 2% for the flow velocity vectors, while that of the ensemble-averaged flow quantities such as turbulent kinetic energy and Reynolds shear stress is about 5%.

In the present study, a Cobra Probe Anemometry system (TFI Series 100 of Turbulent Flow Instrumentation Pty Ltd.), which is capable of measuring all three components of instantaneous flow velocity vector at a prescribed point with a sampling rate of up to 2.0 KHz, was also used to provide time-resolved flow velocity measurement data at the points of interest to supplement the PIV measurements, especially in the far wake behind the wind turbine model.

3. Measurement Results and Discussions

Out of the six degrees of freedom associated with the base motions of a floating wind turbine, the surge motion, which is defined as the linear translation of the wind turbine along the incoming wind direction, is the most dominant linear motion for a floating wind turbine. In the present study, the wind turbine model was first set to be in a surge motion with the frequency of the surge motion being \( f_{\text{surge}} \approx 0.2 \text{Hz} \) and a peak-to-peak surge amplitude of \( A = 120 \text{mm} \).

As described above, a JR3 force-moment transducer was used in the present study to provide time-resolved measurements of all three components of the aerodynamic forces and moments acting on the wind turbine model. While other components of the wind loads can also be important in designing wind turbines and the floating platforms, only the dynamic wind load along the streamwise direction is considered here for conciseness. Figure 6 gives examples of the wind load measurement results in term of the instantaneous thrust coefficient (i.e., \( C_T = F_T/(0.5 \rho U_m^2 \pi R^2) \)) for both the bottom fixed turbine and the model turbine in surge motion. As seen clearly from the time histories of the measured instantaneous measurement results, wind loads acting on the turbine model are highly unsteady with their magnitudes fluctuating significantly as a function of time. The wind loads acting on the bottom fixed turbine (Fig. 6a) were found to be significantly different from those with the turbine base in surge motion (Fig. 6b). While the mean value of the wind loads for the case with the turbine base in surge motion (i.e., \( C_T = 0.40 \)) was found to be slightly higher than that of the bottom fixed turbine (i.e., \( C_T = 0.36 \)), the fluctuation amplitudes of the case with the turbine base in surge motion (i.e., the standard deviation value of the dynamic wind loading being \( \sigma_{CT} = 0.42 \)) were found to be significantly higher than that of the bottom-fixed turbine (i.e., \( \sigma_{CT} = 0.14 \)), i.e., increased by a factor of 3.0 times. It indicates that the fatigue loads acting on wind model would be increased dramatically due to the surge motion of the turbine base, which would ultimately reduce the life time of the floating turbine and the corresponding mooring lines of the floating platform which hold the floating wind turbine.

Figure 6(c) gives the corresponding power spectra of the measured instantaneous thrust forces acting on the wind turbine model (i.e., both the bottom fixed turbine case and the turbine mode in surge motion) through a Fast Fourier Transform (FFT) analysis procedure. For the bottom fixed turbine case (i.e., as indicated in red color), a dominant peak frequency at \( f_0 = 17 \text{ Hz} \) can be easily identified in the power spectra plot. The rotational frequency of \( f_0 = 17 \text{ Hz} \) based on the FFT analysis
of the dynamic wind load measurements was found to agree very well with the independently measured rotational speed of the turbine blades by using a tachometer, i.e., corresponding to the operation tip-speed-ratio of \( \lambda \approx 4.5 \). However, for the test case with the turbine model in surge motion, other multiple peak frequencies can also be observed in the power spectrum plot, in additional to the peak frequency of \( f_0 \approx 17 \). The other peak frequencies seen in the power spectrum plot were found to be the surge frequency of the wind turbine (i.e., \( f_{\text{surge}} \approx 0.2 \text{ Hz} \)) and its harmonic frequencies. As the wind turbine is in surge motion, the relative flow velocity seen by the turbine rotor and the effective angle of attack of the turbine blades would change significantly. This would contribute to the significant fluctuations in the dynamic wind loadings acting on the wind turbine, which are apparent in the time histogram and power spectrum plots of the dynamic wind loads.

As shown schematically in Fig. 5, a high-resolution PIV system was used in the present study to quantify the near wake flow characteristics behind the wind turbine model. Figure 7 shows some typical PIV measurement results with the turbine model in the surge motion, in comparison with those of the baseline case, i.e., behind conventional bottom-fixed turbine as shown in Fig. 7(a). In order to reveal the effects of wave-induced base motion on the turbine wake characteristics more clearly, “motion-locked” PIV measurements were also performed to separate the turbine wake flow characteristics with the wind turbine model passing the neutral position of the surge motion cycles while it is moving with the incoming airflow (i.e., as shown in Fig. 7b) from those with the turbine is moving again the incoming airflow (i.e., as shown in Fig. 7c). The streamwise velocity profiles at two typical downstream locations in the near wake behind the turbine model (i.e., at (at the downstream locations of \( X/D = 0.8 \) and \( X/D =1.7 \)) were extracted from the PIV flow field measurements in order to reveal the changes in the turbine wake flow characteristics due to the surge motion of the wind turbine base more clearly. The velocity profile of the incoming ABL airflow was also given in the plot as the baseline for comparison.

As shown clearly in Fig. 7, in comparison in the velocity profile of the incoming airflow, there is a clear evidence of the velocity deficits in the turbine wake flows behind both the bottom fixed turbine and the turbine model in surge motion. As described in Hu et al.[11] and Tian et al. [12], the velocity deficits behind the wind turbine is the result of energy extraction from the incoming ABL winds by the wind turbine itself. As described in Ozbay et al. [13] and Rosenberg [14], corresponding the “root losses” near the roots of the turbine rotor blades, double-peaks-shaped velocity profiles were observed and understood as the turbine wake characteristics in the near wake region (\( X/D <1 \)). As the downstream distance increases, due to the extensive mixing of the low-momentum wake flow with the high speed airflow from above and/or surrounding undisturbed airflows, the velocity deficits in the turbine wakes would recover gradually[12]. As a result, the double-peaks in the streamwise velocity profiles in the turbine wake would gradually die out, and eventually fully recover further downstream.
It can also be seen that, in comparison to the velocity profile of the incoming flow, there are some slight overshoots at the top region in the near wake regions behind the wind turbine models, corresponding to the local acceleration near the top-tip of the turbine rotor blade, due to the blockage effect of the rotor disk of the turbine blades.

(a). Wake characteristics behind the conventional bottom fixed turbine

(b). Wake characteristics behind the turbine in surge motion while it is moving with the airflow

(c). Wake characteristics behind the turbine in surge motion while moving against the airflow

**Fig. 7**: PIV measurement results in the turbine near wakes with the turbine model in surge motion in comparison with those behind a conventional bottom fixed wind turbine.

Based on the velocity profiles given in Fig. 7, it can also be seen that, during the surge motion, as the wind turbine is moving with the incoming airflow (i.e., moving to the right as shown in Fig. 7b), the velocity deficits in the turbine wake were found to be slightly smaller in comparison to those in the wake behind the bottom fixed turbine, suggesting a reduced energy extraction from the same incoming airflow by the wind turbine due to base motion of the wind turbine. However, when the wind turbine is moving against the incoming airflow (i.e., moving to the left as shown in Fig. 7c), the velocity deficits in the turbine wake behind the turbine in surge motion were found to be greater than those of the behind the bottom-fixed turbine, suggesting an increase energy extraction from the incoming airflow by the same turbine rotor. This trend is anticipated to become more pronounced at the further downstream locations behind the wind turbine model.
In the present study, a Cobra Probe Anemometry system was also used to measure flow velocity and turbulence intensity in the turbine wakes at the points of interest to supplement the PIV measurements. Figure 8 shows the measured mean velocity and turbulence intensity profiles in the far wake behind the turbine model in surge motion, in comparison with those behind the conventional bottom-fixed wind turbine. As shown clearly in Fig. 8(a), in comparison to those of the baseline case (i.e., bottom-fixed turbine), while the velocity deficits in the wake behind the turbine model in surge motion were found to be smaller, especially in the far wake region (i.e., X/D>4.0). Correspondingly, the turbulence intensity levels in the wake behind the turbine model in surge motion were found to be slightly higher. It indicates that the surge motion of the floating wind turbine would only induce greater dynamic wind loadings acting on the turbine, but also affect the turbulent mixing process in the wake flow behind the wind turbine, thereby, impacting the recovery of the velocity deficits in the wake flows behind the floating wind turbine.

4. Summary and Conclusions

An experimental study was conducted to investigate the effects of the wave-induced base motions experienced by floating wind turbines sited in offshore wind farms on their aeromechanic performance and wake characteristics, in comparison with those of a conventional bottom-fixed wind turbine. The experimental study was performed in a large-scale atmospheric boundary layer wind tunnel available at Iowa State University. A scaled wind turbine model was mounted on a motion simulator, which can be programmed to generate translation and rotation motions to simulate the dynamic wave-induced base motions experienced by floating wind turbines sited in offshore wind farms. Kinematic similarity...
between the model and prototype were achieved by maintaining the same ratio between the velocity of the base motions to the airflow velocity at the turbine hub height for both the model and the prototype.

During the experiments, in addition to measuring dynamic wind loads acting on the model turbine, a high-resolution Particle Image Velocity (PIV) system was also used to conduct detailed flow field measurements to characterize the turbulent wake flows behind the turbine model with and without the turbine base in motion. It was found that, the wave-induced base motion would affect the aeromechanic performance of the floating wind turbine significantly. In comparison with those of a conventional bottom-fixed wind turbine, while the mean values of wind loadings were found to increase slightly (i.e., ~ 10% increase), the fatigue loadings acting on the wind turbine model would increase dramatically (i.e., by a factor of 3.0 times) due to the surge motion of the turbine base. It indicates that the fatigue loads acting on wind model would be increased dramatically due to the wave-induced motion, which would ultimately reduce the life time of the floating wind turbines and/or the corresponding mooring lines of the floating platform of the wind turbine.

It was also found that wave-induced base motion would also affect the turbulent mixing process in the turbine wake flow, thereby, impacting the recovery of the velocity deficits in the wake flows behind the floating wind turbines. As a result, it will also affect the distance required between the offshore floating wind turbines in an offshore wind farm. While only the measurements with the turbine model in surge motion were presented here, similar findings were also revealed by setting the wind turbine base in either pitching or heave motion.

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