News Article for RISUD Strategic Focus Area (SFA) Scheme

		Name	Department
1.	**Principal Investigator**:	Yang Hongxing	BSE/PolyU
2.	**Name of SFA:**	Offshore Wind Power Generation	
3.	**Project Title:**	Development of 3D Wind Turbine Wake Models for Energy Efficiency Improvement of Offshore Wind Power Generation Systems	

4. **Third Year Progress/Achievement**

Through close collaborations among the team members in this reporting time period, we have made very good progress towards the completion of this research project. There have been 4 more SCI journal papers and 1 more conference paper arising from this project. Due to Covid-19 outbreak, the wind tunnel experiments at the North China Electric University have been postponed until 2021 so that the completion date of this project has been postponed to the end of 2021 unfortunately. The progress in this reporting year is mainly reflected from the following four aspects:

(1) Improvement of the computation performance of the 3-D wake model

To improve the calculation performance of the proposed wake model, the ANN method is applied to the model. The newly proposed 3-D ANN wake model is trained by the data that have been validated by the measured results of a wind field experiment. The model contains an input layer, two hidden layers and an output layer. The data are divided into a training set (70% of all data), a validation set (15% of all data), and a test set (15% of all data). In this study, the coefficient of determination R2 of all datasets are larger than 0.99999, indicating that the trained 3-D ANN wake model has good performance. Therefore, the wind deficit can be accurately estimated by the 3-D ANN wake model.

(2) Investigation of the wind turbine power modelling based on yaw angle and wake effect

The ANN is adopted to estimate the power generation of wind turbine and wind farm. The main objective of the proposed ANN-wake-power model is to predict the power generation of a cluster of wind turbines at given conditions, including incoming wind speeds, wind directions, and yaw angles of selected wind turbines. The ANN-wake-power model considers the influence of wake and yaw angle of wind turbine. Therefore, the power of wind turbines can be accurately estimated.

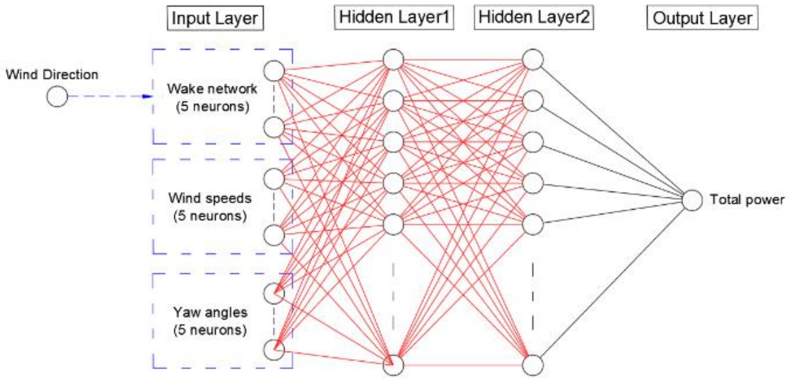

Figure 1 Structure of the ANN-wake-power model

(3) Optimization of the yaw angle based on the proposed wind turbine power modelling

For multiple wind turbines, yaw misalignment may have a beneficial effect because it can control the aerodynamic wake and reduce energy losses of downstream wind turbines. The optimized total power ratios are compared with the original data. The incoming wind speed is assumed to be 9 m/s. The results include the power ratio optimized in wind directions of 150-200°. As expected, in the wind directions under the wake effect, the power ratios with optimized yaw angels are generally greater than the actual ratios of the same wind direction. All optimized power ratios are larger than 0.96.

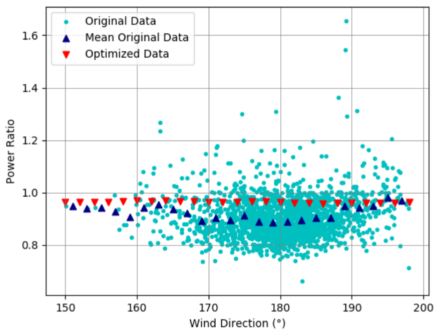

Figure 2 Comparison of original data and optimized results

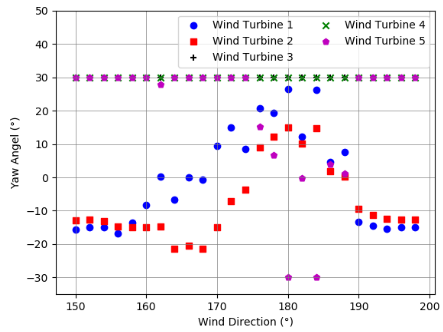

Figure 3 Optimized yaw angles in the angle range of -30° to 30°

To obtain the optimal results, wind turbines in different wind directions should be controlled by individual strategies. The first and last turbines (WT10-1 and WT10-5) should be carefully controlled to avoid either affecting other turbines or being affected by wakes of other turbines. Whereas for WT10-3 and WT10-4, the yaw angles can be set to the maximum positive value.

(4) Study on the impact of wind turbine hub height on the wind farm

In a wind farm, due to the wake effect, the change in hub height not only affects the wind turbine itself, but also other nearby wind turbines. For example, when changing the downstream wind turbine, the influence on the downstream wind turbine itself is much more complicated. When increasing the hub height, the equivalent wind speeds and the power outputs at all downstream positions increase significantly. When decreasing the hub height, where the increment of hub height is smaller than zero, the equivalent wind speed does not change monotonically with the hub height.

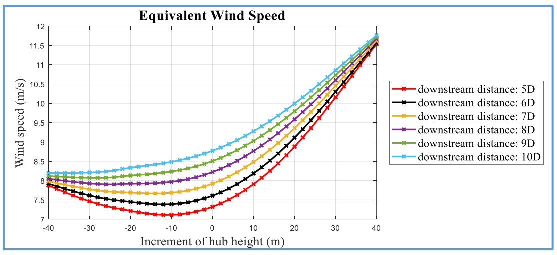

Figure 4 Impact of the downstream wind turbine's hub height on the equivalent wind speed of the downstream wind turbine.

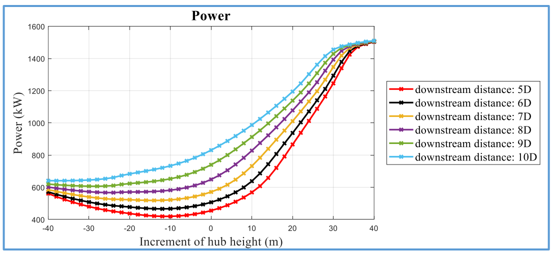

Figure 5 Impact of the downstream wind turbine's hub height on the power of the downstream wind turbine.

Generally, the power output performance of a wind turbine corresponds to its equivalent wind speed. However, duo to the power curve, a higher equivalent wind speed will not always lead to a higher power output performance. Especially, when the equivalent wind speed is larger than the rated wind speed, the power output will maintain the rated power. Therefore, both the equivalent wind speed and the power curve should be carefully considered for the power performance of the wind turbine.