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. **Progress/Achievement (***in layman's language, no more than two A4 pages***)**

Hong Kong is a typical coastal region with a large amount of offshore wind energy resources, but there is no commercial wind farm yet. This project investigates wake characteristics and loads of wind turbines in complex environments, proposes a wind farm optimization program, and optimizes the layout of Hong Kong's offshore wind farm. The completed research contributes to the quick development of offshore wind industry and the carbon neutrality target in Hong Kong. The concept of 3-D wake effect and wind farm's integrated optimization is the right direction towards the improvement of power performance of offshore wind farms, rendering the world more resource efficient and less dependent of Hong Kong on other economies.

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. All proposed targets have been achieved. 14 SCI journal papers and 6 conference papers have been published from this project. The output of this project has also been presented as a keynote speaker by Prof. Yang in the 1st International Chinese Conference on Energy and Built Environment (19th to 22nd July 2019, Chengdu). The progress is mainly reflected from the following three aspects:

(1) Novel 3-D wake models have been developed.

New analytical 3-D wake models for single and multiple wind turbines have been successfully developed to describe the wind distribution in a wind farm. It can be used to calculate the wind velocity at any spatial position with high accuracy and little computational cost. This is the main aim and objective of the project.

Then, the available wind tunnel measurement data are used to validate the 3-D wake model. For the horizontal wake profile, most errors were within ±5%, while for the vertical wake profile, most errors were within ±3%. An analytical 3-D wind turbine wake model for multiple wind turbines is also developed. The available wind tunnel measurement data are applied to validate the model. For the chosen two layouts, the wake model also predicted the wake effect with an acceptable precision. Figure 1 and Figure 2 show the validation results of the novel wake models.

(2) Wind field experiment has been completed.

The proposed onsite wind farm experiments were conducted in Shiren Wind Farm in Zhangjiakou, Hebei Province, China. Two lidars were rented to measure the wake effect at the

wind farm. One experiment takes two wind turbines into account to measure the upstream-and-downstream patterns. One of the measured periods is shown in Figure 3 as an example, i.e., at 8:33am on 5th March 2019.

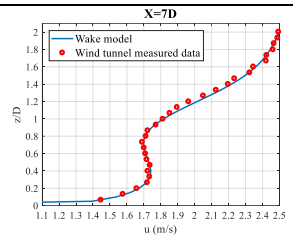

Figure 1 Validation of the 3-D model in the vertical direction

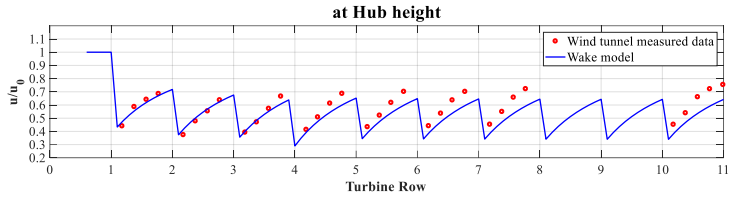

Figure 2 A characterization of the average wind speed at the hub height

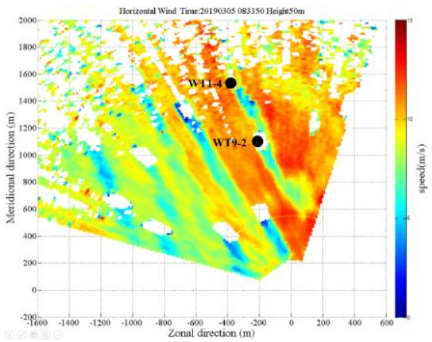

Figure 3 PPI scanning result in the plane at hub height

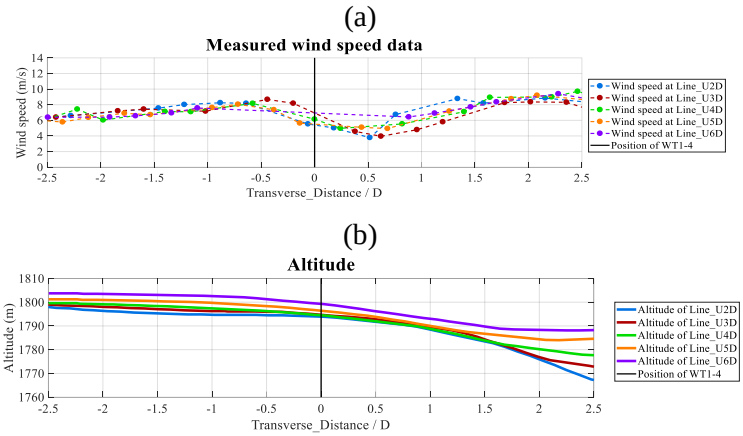

Figure 4 (a) Measured wind speed; (b) Altitudes in the crosswind direction (behind WT1-4)

The wind speed data was filtered based on the analyzing lines. The measured wind speeds and the altitudes in the corresponding lines are shown in Figure 4. From the results, the largest deficit of wind speed was in the near-turbine zone. The range of the wake-influenced area varied among different crosswind lines. The wake width increased gradually in the downwind direction. The terrain slope and local obstacles are the main reasons that the wake distribution was asymmetry about the centerline.

(3) Wind tunnel experiments have been successfully completed.

Two wind tunnel experiments have been conducted to investigate the wake characteristics in the University of Hong Kong. In the first wind tunnel experiment, two wind turbine models with the same size are applied in the experiments. In another experiment, fence wooden is applied to change the roughness, and laser is used to record the result. The set-up of the experiment is shown in Figure 5.

In the first experiment, measurement results show that the wake loss after the wind turbine is not obvious. This is mainly because under a single incoming wind speed, the incoming turbulence is very low and the corresponding wake expansion coefficient is high, resulting in high wake velocity. It is observed that with the increase of streamwise distance, the wake velocity does not gradually increase, but fluctuates, mainly because the wall effect of the wind

tunnel has some impact on the wake recovery. In another wind tunnel experiment, wind speed and turbulence intensity are measured and analysed to unveil the wake characteristics.

Figure 5 Set-up of the second experiment

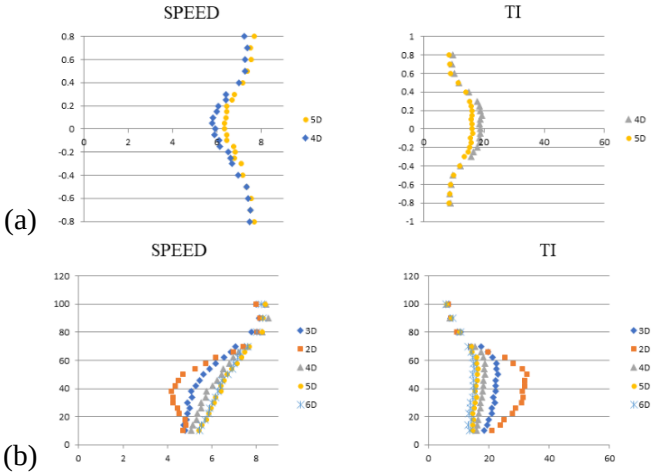

Figure 6 Experimental results: (a) speed and turbulence intensity in horizontal direction; (b) wind speed and turbulence intensity in vertical direction