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

After one year's effort, we have made very good progress towards completion of this research project. The progress are mainly reflected from the following four aspects:

(1) A novel 3-D wake model for single wind turbine has been developed.

We have successfully developed the proposed new analytical 3-D wake model 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 in this stage.

We then used available wind tunnel measurement data 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%.

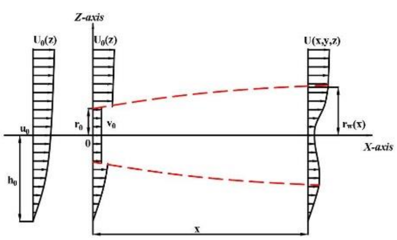

Figure 1 Schematic diagram of the 3-D wake model

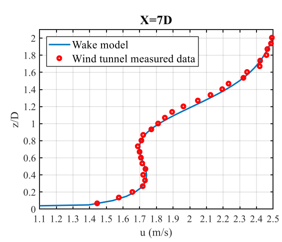

Figure 2 Vertical comparisons of the measured data and the 3-D model at the 20D distance

(2) A new 3-D wake model for multiple wind turbines has been developed.

We further developed an analytical 3-D wind turbine wake model for multiple wind turbines. We applied available wind tunnel measurement data to validate the 3-D multiple wake model. For the chosen two layouts, the wake model also predicted the wake effect with an acceptable precision.

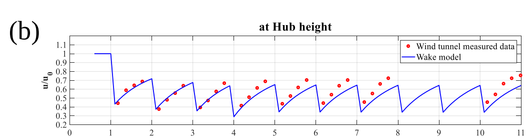

Figure 3 A characterization of the average wind speed at the hub height.

We obtained some prediction of wake distribution of two layouts of the staggered array of miniature WTs from the 3-D wake model. The feasibility of applying the 3-D multiple wake model to depict the wind speed deficit has been assessed.

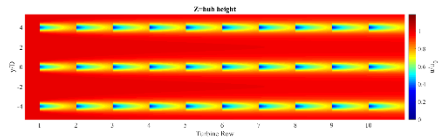

Figure 4 X-Y view of wind speed at Z=hub height

(3) The MPGA optimization program has been updated with foundation repowering strategy.

To minimize the levelised cost of energy (LCoE) of offshore wind farms, we analysed the repowering strategies. In the repowering optimization strategy, the foundations are not dismantled immediately after the service time, so the lifecycles are extended to two generations' service time. This strategy can save the costs of removing the first foundations and installing the second foundations.

The repowering strategies can decrease LCoE. We demonstrated a case analysis in Sha Chau Island sea area. Taking the chosen offshore area (3,740m×5,828m) as an example, an 226.8MW offshore wind farm (with 54×4.2 MW WTs) can generate 2.44×10^4 GWh electricity in 20 years. If the repowering strategy is applied, by reusing the WT foundations and replacing the original WTs with the optimized WT combination, the LCoE is expected to reduce to only 0.913 HK$/kWh. From this case, we know that the proposed method of offshore wind farm layout optimization is practical and effective.

(4) Nonuniform wind farm optimization with multiple types of wind turbines has been realized.

We studied the spacing restrictions of wind farms and the layout optimization problem of nonuniform wind farms. We presented the Directional Restriction method. In the aligned layout design, the Directional Restriction improved the energy utilization ration in a uniform wind farm by 14.44%. The similar increase in the optimized layout design was 0.93%.

We used the Directional Restriction and the Multi-Population Genetic Algorithm in the layout optimization of a commercial nonuniform offshore wind farm. We chose the potential site in Sha Chau Island seawater area in Hong Kong. The designed nonuniform offshore wind farm had an annual average power output of 98.57 MW. It demonstrated that the proposed optimization method is practical in designing wind farm, and Hong Kong offshore area is an ideal region to develop the offshore wind power.

We also found that with the Directional Restriction, the wind condition has a considerable influence on the layout of wind farm. If wind directions are highly-centralized, the optimal layout tends to be narrowly arrangement, vice versa. Meanwhile, the restricted area of the Directional Restriction tends to be small. Therefore, the application of the Directional Restriction can also improve the capacity of wind farms by installing more wind turbines.

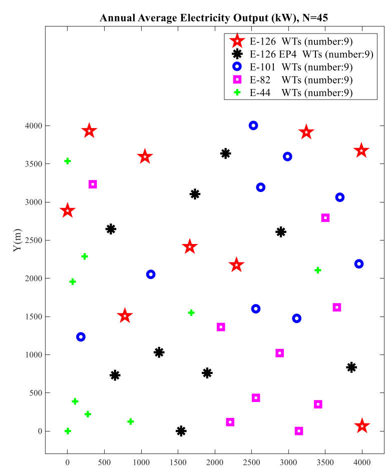

Figure 9 Optimized layout of the nonuniform wind farm in Hong Kong