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Optimized spacing and thrust for a row of aligned turbines for maximum power production

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The objective of the paper is to present computations of the optimal spacing and thrust for maximum power production for a row of aligned turbines within a specified maximum length of the row. This will be done for different free wind speeds, number of turbines in the row and ambient turbulence intensities.

The model to be used will be the basic sub models (eddy viscosity model + model for inserting a deficit from a turbine) of the DWM model[1,2], however without the meandering part. Importantly, the model is here used in a sequential way so that a sub model for merging of the wakes is avoided. Modelling the merging wakes is generally the weak part of wind farm models using engineering wake models. In particular modelling wake merging is challenging if both wind speeds below and above rated power is considered as is the case in the present study.

The sequential model approach as described in[3] is illustrated in Figure 1 for a row of 8 turbines with a spacing of 6D and at a wind speed of 14m/s which is slightly above rated power wind speed. In the left graph the approach is illustrated and the right graph shows the inflow profiles for the 8 turbines. We use look up tables for the power and thrust curves for a 2.1MW pitch regulated, variable speed turbine with an 80m rotor. The sequential wake model is integrated with an optimizer in order to maximize the total power output of the row. We will show optimized variable spacing for different wind speeds and turbulences intensities and another set of optimization results where the turbines can be downregulated in thrust.

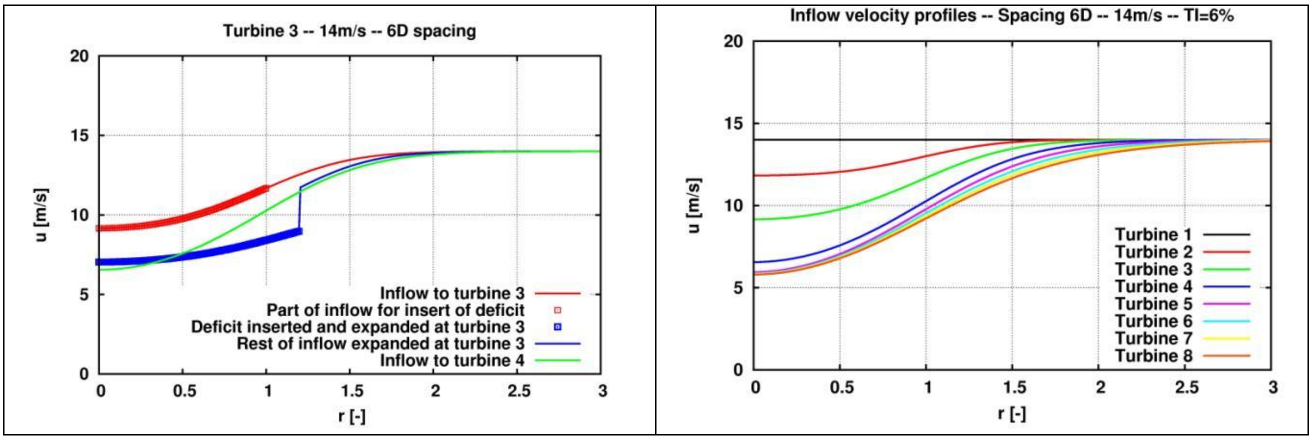

Figure 1: Left graph shows the sequential procedure for modelling an aligned row of 8 turbines, here exemplified with the details of deficits from turbine 3 to 4. Inflow to turbine 3 is the red curve and based on the mean inflow the Cp and CT for the turbine is found in a look up table. Based on the CT a deficit is inserted (blue curve) which is the input to the eddy viscosity model[2] for developing the deficit downstream and give the inflow profile (green curve) to the next turbine. The right graph shows all the inflow profiles to the 8 turbines in the row for a free wind speed of 14m/s.

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[1] Larsen et al., “Wake meandering - a pragmatic approach,” Wind Energy, 11, 2008, pp. 377–395.

[2] Madsen et al. “Calibration and Validation of the Dynamic Wake Meandering Model for Implementation in an Aeroelastic Code,” J. Sol. Energy Eng., 132(4), 2010.

[3] Madsen et al., “Wake Flow Characteristics at High Wind Speed.” 34th Wind Energy Symposium. American Institute of Aeronautics and Astronautics Inc, AIAA 2016.