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# Numerical study on the limit of power extraction by a dense cross-stream array of wind turbines

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**Abstract**

A numerical study is presented on the upper limit of power extraction by a dense cross-stream array of wind turbines, using 3D Reynolds-averaged Navier-Stokes simulations of flow over porous discs. The main objectives are: (i) to investigate the effect of 'local blockage' due to neighbouring turbines on the limit of power extraction; and (ii) to clarify how this effect compares with the effect of 'local flow acceleration' obtained by staggering the array in the streamwise direction. Some unconventional array configurations with vertical turbine arrangements, following the so-called 'multi-rotor' concept, are also investigated. Results show that the limit of power extraction by a non-staggered array increases moderately with the number of turbines arrayed (about 5% increase in the power coefficient compared to the Betz limit when 9 turbines are arrayed side-by-side). This power increase due to the local blockage can be enhanced further, but only slightly for the case of 9 turbines, by arranging turbines vertically as well as horizontally. Staggering the array in the streamwise direction may increase the power of downstream turbines due to the effect of local flow acceleration but reduce the power of upstream turbines as the local blockage effect diminishes, resulting in a total power reduction.

*Keywords*: Blockage effect; Efficiency; Multi-rotor; Staggered array; Wind farm

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