FLOATECH

D4.1. Active Wake Mixing

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THE FUTURE OF FLOATING WIND TURBINES

Work package four (WP4) of the FLOATECH Project is devoted to the development of fundamental knowledge, technology and control algorithms for the excitation of the wake of a floating offshore wind turbine (FOWT). Optimum excitation of the wake may augment the position of wake breakdown and thereby improve wake recovery. This has a range of important applications including the optimal farm turbine placement and reduction of unsteady loads on staggered turbine arrays. In order to harness the full potential of the excitation methods which shall be investigated within the FLOATECH project, a fundamental understanding of the physics underlying the process of wake breakdown and recovery is necessary. Deliverable 4.1 of WP4 is aimed directly at providing this foundation in order to facilitate discussion and analysis of excitation methods and results.

A thorough literature review of different types of instabilities which may occur in a helical wake system was first carried out. This demonstrated that within the framework of linear perturbation theory, there exists three types of instabilities which may occur [1]. These are referred to as the short-, medium- and long-wavelength instabilities. The medium-wavelength instability is commonly referred to as the mutual inductance instability as the underlying physical mechanism which leads to the destabilization of the wake topology is the interaction between neighboring vortex filaments. Due to the highly complex fluid-dynamic interactions which take place beyond the linear regime of instability growth, analytical treatments become unsuitable and numerical techniques must be applied. A review of the literature of numerical investigations was carried out. It was found in a range of studies that the mutual inductance instability most grows most rapidly and is commonly the mechanism which leads to to wake breakdown for realistic scenarios of an operating wind turbine. Within the context of the knowledge gained in the review of the underlying physics, a range of excitation methods were reviewed. Particular emphasis was placed on the HELIX excitation method [2] which uses a cyclic perturbation of the blade pitch angles to introduce a deflection of the wake. A simple analytical analysis was carried out to establish a link between the excitation frequency of the HELIX method and the perturbation frequencies of the linear perturbation theory.

A range of simulations were carried out to demonstrate the ability of QBlade Ocean in the simulation of wake excitation for offshore wind turbines. The ability of the VPML model to capture high-order physical interactions, such as those occurring in the nonlinear phase of the aforementioned modal instabilities. A range of simulations using the free vortex-filament aerodynamic model within QBlade Ocean demonstrated that turbine motions characteristic of a FOWT indeed excite the wake and gives rise to earlier wake breakdown. The efficacy of the HELIX method was then demonstrated for a range of operational states and excitation frequencies. Finally, the influence of a fully turbulent inflow was investigated and demonstrated that the effect of turbulence is to further excite the wake and gives rise to quicker wake recovery. These results demonstrated that the use of the relative motion of the turbine floater and the HELIX method are indeed practical methods for excitation of the wake of a FOWT.

References:
[1] S. Widnall. “The stability of a helical vortex filament.” In: *J. Fl. Mech.* 54 (1972), pp. 641–663.
[2] J. A. Frederik, B. M. Doekemeijer, S. P. Mulders, and J. W. van Wingerden. The Helix approach: Using dynamic individual pitch control to enhance wake mixing in wind farms, *Wind Energy*, **23**, 1739-1751, 2020.