Towards a Modular Upscaling Strategy for Utility-Scale Airborne Wind Energy

Jochem De Schutter¹, Rachel Leuthold¹, Thilo Bronnenmeyer², Reinhart Paelinck², Moritz Diehl¹
¹University of Freiburg, ²Kiteswarms Ltd.

The prevailing industrial upscaling strategy towards utility-scale AWE systems is based on single-kite systems and relies on increasing aircraft size until the desired power output in the MW range is reached. This strategy suffers from many of the drawbacks associated with the upscaling of conventional wind turbines, such as increased costs related to production, transport, repair, challenging structural mechanics, etc.

It has been shown in simulation that AWE systems based on multi-kite topologies could drastically reduce the required aircraft size for a given power demand due to the intrinsically low main tether drag [1]. However, safety and efficiency concerns limit the amount of kites that can be added to a single multi-kite system.

Hence the idea of extending the design space to multi-layer multi-kite configurations, obtained by stacking multi-kite systems on a shared main tether, as illustrated in the Figure. This concept naturally allows to increase the total amount of harvesting area together with the number of aircraft in the system. It results in an efficient and modular upscaling strategy, effectively decoupling aircraft sizing from power demand. Therefore, multi-layer topologies could enable the realization of utility-scale AWE systems based on relatively small, mass-producible aircraft.

This research aims to assess the upscaling advantage of multi-layer relative to single-layer multi-kite topologies for rigid-wing aircraft systems. Optimal control is applied to simultaneously optimize both system design and flight trajectories for a large set of possible topologies. The models are based on 6DOF aircraft dynamics and low-order layer-wise induction models, similar to those presented in [2]. The optimal control problems are formulated and solved using the open-source AWE optimization framework awebox [3]. The results are computed for different power output requirements associated with industry-relevant wind sites. Flight trajectories and required aircraft size are compared for considered topologies. Finally, results for both drag-mode and pumping-mode systems are compared and discussed in detail.

References: