Large Eddy Simulation of Airborne Wind Energy Systems flying optimal trajectories in turbulent wind

J.-B. Crismer, F. Trigaux, T. Haas, M. Duponcheel and G. Winckelmans

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Airborne Wind Energy Systems (AWES) consist of rigid-wing aircraft or soft kites connected to the ground by a tether and harvesting power from the wind. Pumping-mode AWES are considered here: they generate power during the reel-out phase and consume a fraction of this power during the reel-in phase. Those devices fly complex trajectories which require advanced control strategies. In Haas et al. [1], a LES framework was used to study AWES farms in realistic turbulent winds. The AWES were solely represented by their main wings, each being modelled as a single actuator line (AL) in the LES. The system dynamics were computed using a 3DOF point-mass model coupled to a closed-loop path tracking controller from the optimal control toolbox `awebox` [2] .

In the present work, we aim at developing a LES framework to study more realistic models of AWES in realistic turbulent winds. The reference rigid wing AWES of [3] is considered and is modeled using multiple ALs; one for each lifting surface. The toolbox `awebox` is also used to generate reference trajectories and control the 6DOF rigid-body motion of the aircraft.

As a first step, the device is flown on a prescribed trajectory, using the kinematics and the control inputs (deflection of control surfaces) obtained using the trajectory optimization tool of `awebox`. The aerodynamic loads are measured and are then compared to those obtained by the optimizer. In a second step, preliminary results of a closed-loop controlled flight (using a MPC controller) will be presented.

A simplified model is also developed in order to provide a faster platform for the investigations of AWES in turbulent winds and development of the controller: the aircraft is represented using multiple lifting lines (LL), and it flies in a frozen turbulent flow field; one from the LES solver taken at some time. The output of the AL and LL models are also compared.

Even though the present work focuses on rigid-wing AWES, the simulation framework is being developed so as to also handle soft kites in the future. Flying in other environments, such as crossing strong wakes from wind turbines, will also be considered. The methodology will then allow to study the behavior of AWES in many conditions, and asses the efficiency of various control strategies.

References

[1] T. Haas, J. De Schutter, M. Diehl, and J. Meyers. Large-eddy simulation of airborne wind energy farms. *Wind Energy Science*, 7(3):1093–1135, 2022.

[2] awebox: Modelling and optimal control of single- and multiple-kite systems for airborne wind energy. `https://github.com/awebox/awebox`.

[3] Dylan Eijkelhof, Sebastian Rapp, Urban Fasel, Mac Gaunaa, and Roland Schmehl. Reference design and simulation framework of a multi-megawatt airborne wind energy system. *Journal of Physics Conference Series*, 1618:32020, 09 2020.