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Power Smoothing in Utility-Scale Airborne Wind Energy Trajectory Optimization

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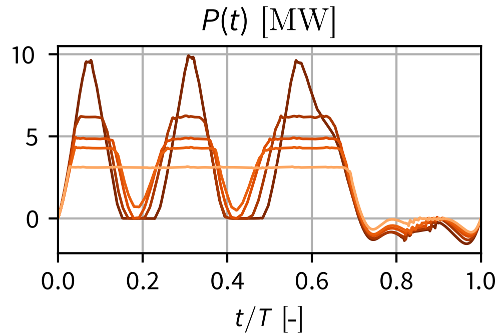
The prevailing vision for upscaling airborne wind energy systems boils down to increasing the aircraft aerodynamic surface until the desired power output is attained. One side-effect of this strategy is the increased influence of the aircraft mass on the power-optimal flight trajectories and associated high peak-to-average power ratios (PAPR). The gravity-induced power peaks would then lead to disproportionally expensive components in the electrical machinery.

It is however possible, both for lift- and drag-mode systems, to smoothen out the power peaks for heavy AWE systems by adapting the flight trajectory accordingly – at the cost of a lower average power output.

In this work, we propose a variation of the standard optimal control problem formulation which allows us to investigate this trade-off in a straightforward fashion. To illustrate the capability of the proposed formulation, we compute the Pareto efficiency front for a utility-scale single-aircraft pumping system and we discuss how the control strategy is altered to achieve the PAPR reduction. These steps are repeated for a triple-aircraft system of equal power output and the Pareto fronts are compared.

The simulations show that in this case study, the PAPR of a 55 m wing span (2.5 MW) single-aircraft system can be reduced from 4 to 2 by a loss of 10% of the average power output compared to a PAPR reduction from 2.6 to 2 combined with a power loss of 2% for a system with three aircraft of 30 m wing span each.



Possible mechanical power output profiles of a utility-scale pumping single-aircraft system on the Pareto efficiency front of average power vs. PAPR.

The proposed problem formulation has been implemented in the open-source AWE optimization toolbox AWEbox [1] and the simulation code will be made publicly availabe.

References:

[1] awebox. https://github.com/awebox/awebox