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Reverse Pumping for Rigid Wing Airborne Wind Energy Systems at Large Scale

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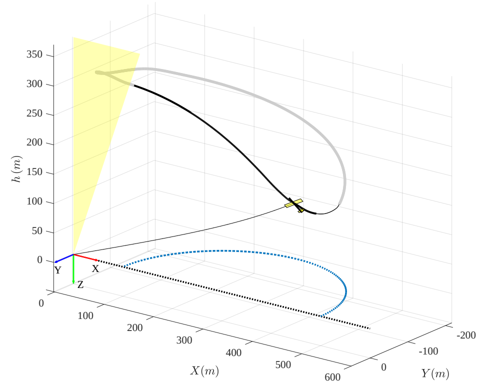
The problem of continuous flight of pumping Airborne Wind Energy Systems (AWES) with rigid wings in low-wind conditions is addressed. The considered operational mode, referred to as "reverse pumping" in the literature, aims to keep the kite airborne in case of low wind, instead of carrying out a time-consuming vertical landing. In [1], the authors investigated optimal reverse pumping in open loop in connection to a carousel launch maneuver for a small-scale system. In [2], reverse pumping is studied theoretically, considering a twin-kite setup and a laboratory-scale experimental setup.

In this work, we propose an approach to design a feedback control system to obtain reliably a large-scale reverse pumping maneuver, with tether length of the order of hundreds of meters, at the same time being relatively easy to implement and tune. The strategy features four phases: a pre-winch-launch, a winch-launch, a linear-glide, and a turn-away phase. A high-level state machine governs the switching among the four phases with a feedback strategy, while low-level control loops on the ground station and on the kite carry out the maneuvers prescribed for the current phase. Simulation results obtained with a high-fidelity model showcase the feasibility and effectiveness of the approach. The method's main advantages are: enabling operation below cut-off wind speed, reducing the hysteresis losses by making a smooth transition between cut-in and cut-off wind speed, and reducing the system mass; since the approach enables launching the system with a shorter tether length than a standard winch launch method, it decreases the hovering time required to enter production and allows the designers to down-size the onboard energy storage for the VTOL system.



Simulation results: flight trajectory in the 0 m/s wind speed scenario for three full cycles.

References:

[1] Gillis, J., Goos, J., Geebelen, K., Swevers, J., and Diehl, M., Optimal periodic control of power harvesting tethered airplanes: How to fly fast without wind and without propellor?, American Contr. Conf., pp. 2527–2532 (2012).

[2] Lozano, R., Dumon, J., and Hably, A., Reverse pumping: Theory and experimental validation on a multi-kites system, 17th Inte. Conf. on System Theory, Control and Computing (ICSTCC), pp. 311–318 (2013).