Kiwee One airborne wind turbine with 1 m rotor diameter (1 July 2017)

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Inertia-Supported Pumping Cycles with a Roto-Kite

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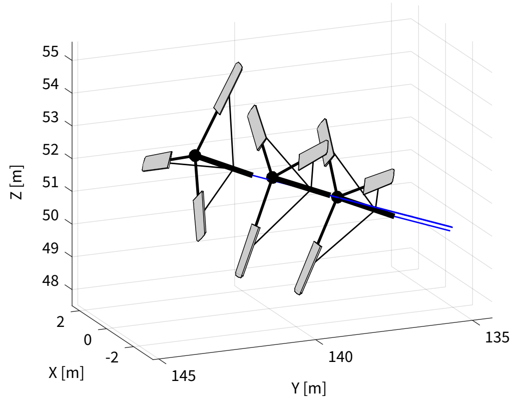
It has been shown in simulation that multiple-kite systems show great potential over single-kite systems due to reduced tether drag [1]. Rotary kites are an interesting subclass of multiple-kite systems, because they are easy-to-build and yield simpler dynamics. Additionally, rotary kites offer a possible 'elegant solution' for the take-off problem of more general multiple-kite systems, where the rotary kite is launched first, and the tethered kites are released and unrolled from the central point after take-off at high altitude.

Here, we present recent simulation results for a pumping airborne wind energy system consisting of a fast spinning rotor – the roto-kite – with three blades, which is connected to a ground-based generator by a tether. The airborne system is controlled by both collective and cyclic pitch control. Power is generated by a pumping cycle, i.e., by unrolling the tether in the generation phase, and winding it up in the retraction phase, which is typically characterized by lower tether tension. For the simulation study, systems with varying airborne area are modelled by differential-algebraic equations and analysed with the help of numerical optimal control techniques.

The surprising result of the optimal control computations is that the overall system efficiency can reach nearly 100% of Loyd's limit, even though the retraction phase uses almost 50% of the cycle time, which is chosen to be very short by the optimization solver. This gain in efficiency of 10-15% compared to conventional pumping cycles is possible by exploiting the inertia of the spinning rotor to store energy harvested in the retraction phase, as detailed plots of the power flow between the wind, the tether, and the roto-kite's rotational energy reveal. This counterintuitive behaviour is discussed in detail, and possible use cases for the discovered new cycle, such as sinusoidal pumping cycles, are presented.



Three stages of a simulated power-optimal pumping trajectory of a roto-kite.

References:

[1] Zanon, M., Gros, S., Andersson, J., Diehl, M.: Airborne Wind Energy Based on Dual Airfoils. IEEE Transactions on Control Systems Technology, Vol. 21, No. 4 (2013)