Optimization of Long Trajectories of Dual-Kite Airborne Wind Energy Systems with Many Cycles

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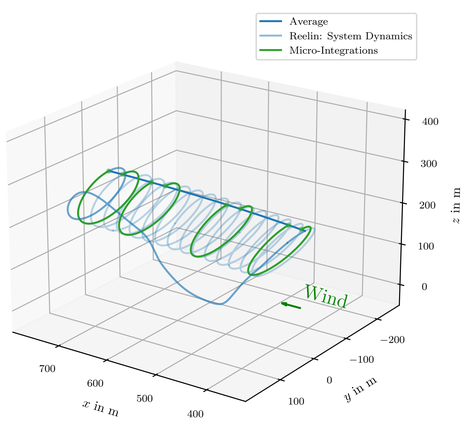
Motivation

When simulating and optimizing the trajectory of a pumping dual-kite AWE kite system, a large number of cycles in the reel-out phase corresponds to a large optimization problem that is numerically expensive to solve.

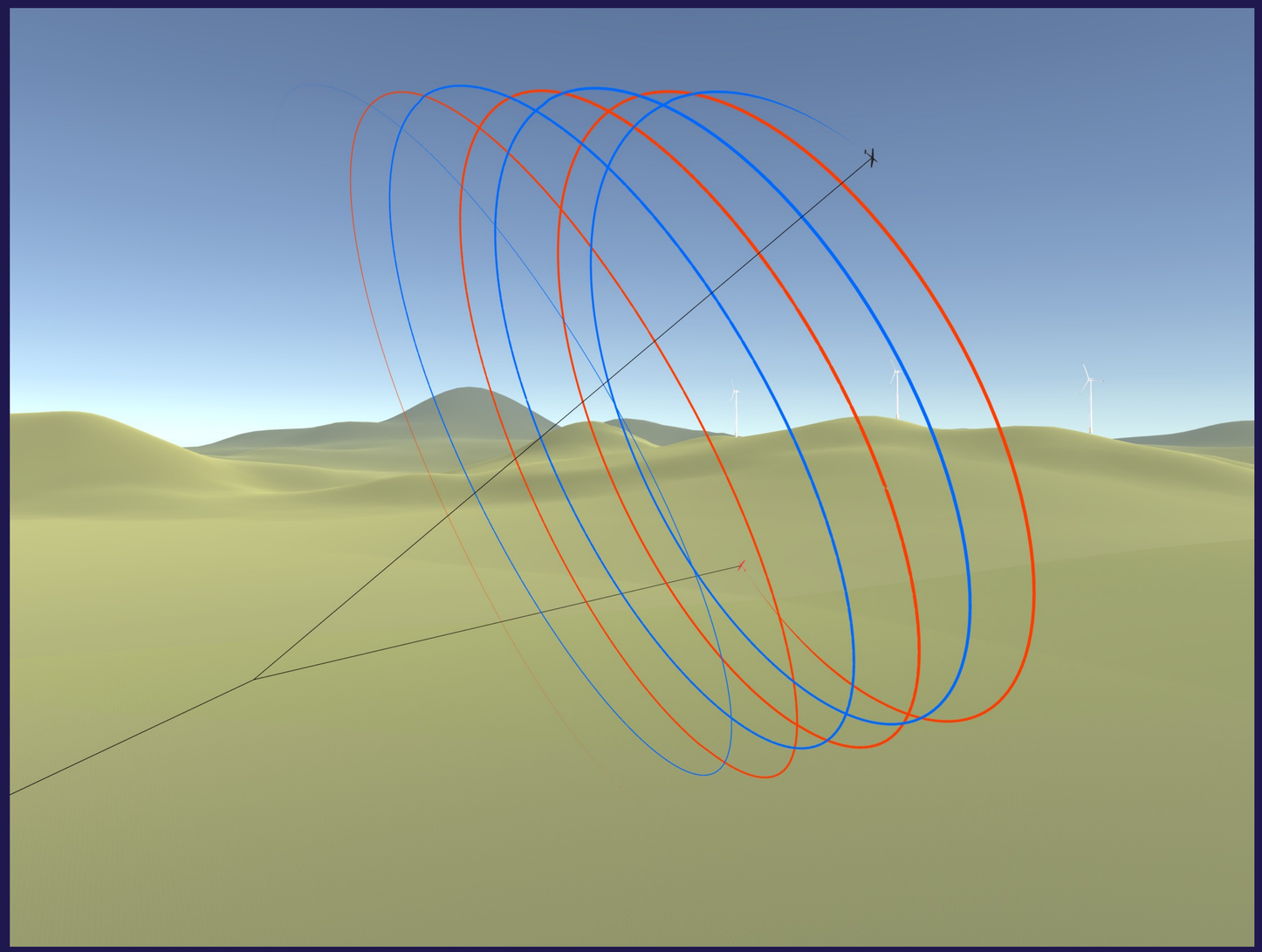
$$\begin{aligned} \max_{\substack{x(\cdot),u(\cdot),\\ t_\mathrm{f}}} \quad & P_\mathrm{gen}(x,u,t_\mathrm{f}) \\ \text{s.t.} \quad & \dot{x} = f(x(t),u(t)), \quad \forall t \in [0,t_\mathrm{f}], \\ & 0 \le h(x(t),u(t)), \quad \forall t \in [0,t_\mathrm{f}] \end{aligned}$$

Stroboscopic Averaging Method

By simulating only a subset (4) of the larger number of the slowly changing cycles, we can reduce the solution time and number of variables of resulting NLP.



We can **efficiently optimize** the trajectory of dual-kite airborne wind energy systems **over a long horizon**



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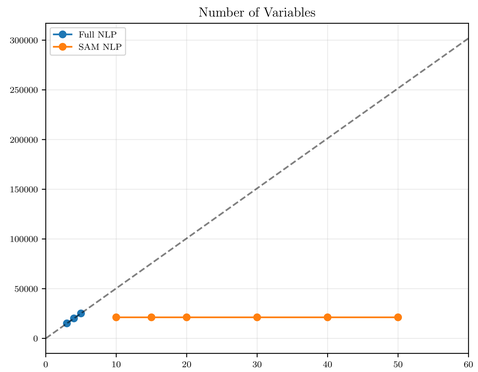
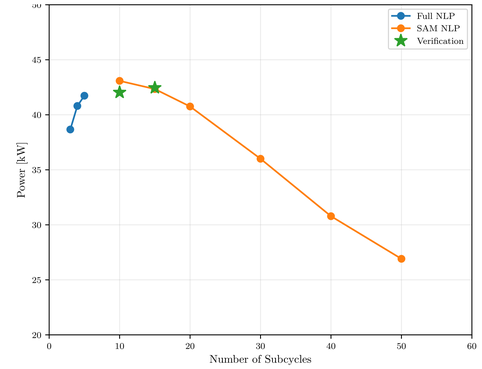
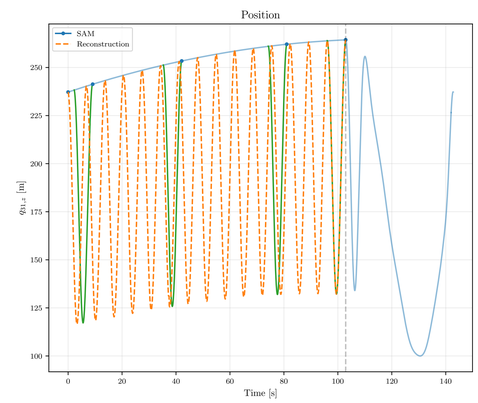
Additional Details





Full Solution & Validation

We can ‘reconstruct’ the full solution by interpolating the 3-cycle solution, and validate the trajectory using a tracking-MPC.



References

[1] “Efficient Numerical Optimal Control for Highly Oscillatory Systems”, J. Harzer, J. De Schutter, M. Diehl, *IEEE Control Systems Letters (2022)*