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Optimal Flight Path for Fly-Gen Airborne Wind Energy Systems

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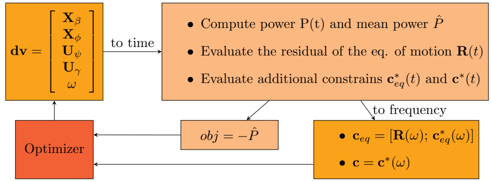
The computation of optimal trajectories for power production of Airborne Wind Energy Systems (AWES) is an active research field, where different optimization problems often lead to different trajectories [1]. Optimal trajectories are evaluated offline or during operation and the computed paths are typically used as guidance inputs to the control system. Optimization problems can be characterized by low-fidelity models, where strong assumptions are taken, or higher fidelity, which can better describe the physics. Low-fidelity dynamic models are suitable for trajectory optimization problems since they allow to obtain insightful physical understanding of the systems. The present work introduces an optimization problem for flight paths of Fly-Gen AWES which is based on the model in [2], adapted for Fly-Gen AWES.

The dynamics of the system is stated in the frequency domain through a harmonic balance formulation due to its inherent periodic character. This allows to reduce the problem size by solving only for the main harmonics. Indeed, the time evolution of trajectory is described by the Fourier coefficients of elevation and azimuth ($\mathbf{X}_\beta$ and $\mathbf{X}_\phi$), which are included as optimization variables in the optimization problem. Moreover, the Fourier coefficients of the time evolution of the on-board wind turbines thrust and of the AWES roll angle, which are the two control inputs, ($\mathbf{U}_\gamma$ and $\mathbf{U}_\psi$) are included as optimization variables as well. The optimizer then maximizes the mean power production ($\hat{\mathbf{P}}$) while respecting the dynamics, which is treated as a set of nonlinear equality constraints thanks to the frequency-domain formulation ($\mathbf{R}(\omega)$). Additional nonlinear constraints (e.g. minimum elevation angle) are expressed in frequency and included in the optimization.

To conclude, the present work aims at giving a detailed physical understanding of optimal paths, by highlighting their characteristics. Optimal trajectories will be analyzed as function of non-dimensional parameters to generalize results.



Optimization framework for the optimal flight path evaluations.

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[2] Fernandes, M.C., Paiva, L.T. and Fontes, F.A.: Optimal Path and Path-Following Control in Airborne Wind Energy Systems. Advances in Evolutionary and Deterministic Methods for Design, Optimization and Control in Engineering and Sciences (pp. 409-421). Springer, Cham, 2021.