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An Analytical Performance Model for AP-4 Conceptual Design Phase

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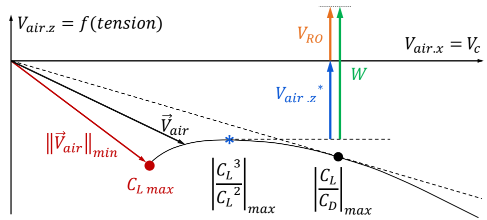
The conceptual design phase of a utility-scaled Airborne Wind Energy System (AWES) spans over the sizing of the tethered-aircraft, the power generator and the tether. The design is further complicated by the fact that these systems cannot be optimized separately given their interdependencies. Numerical approaches of high simulation fidelity have been developed at Ampyx Power, to anticipate on techno-economic performance levels. Yet in a conceptual design scope, these models may be already too detailed, or computationally too expensive to search the design space efficiently. Besides, numerical approaches may lead to obscure results, where the effects of various design choices are combined and their isolated contribution to the overall trend cannot be easily distinguished. If the system behaviour can be approximated by integral equations, then our understanding of the mechanisms at play and of their corresponding governing variables can be made fully explicit.

We present here a physics-based approach to performance modelling that emphasizes a key metric of gliding performance: the 'sink rate' of the tethered-aircraft against the incident wind. The resulting analytical model, which relies on the steady-state aircraft dynamics, approximates sufficiently well the overall behaviour of the system to account for the main trade-offs at play. This approach provides a different point of view than the existing literature, even though it leads to well-established results. It is easily understandable and applicable to various steady-state variations of the well-known straight-line case [1]. Besides, it provides additional levels of insight about the power curve, specially at the operational limits.

This model enables to investigate key trade-offs between high-level design variables, which will be illustrated. We will detail how this analytical approach helped to formulate an airfoil optimization function and more generally, how it can help to reduce the design space and orientate the grid search. Finally, we will present an overview of the various numerical tools used at Ampyx Power and how they integrate into an overall input-output toolchain. We will describe how this quantitative approach is associated to the analytical model described above to converge towards candidate designs for AP4.



Remarkable points along a glide polar: stall, minimum sink rate and maximum glide ratio along with remarkable speed vectors.

References:

*[1] Loyd, M. L.: Crosswind Kite Power. Journal of Energy **4**(3), 106-111 (1980)*