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Power Losses Analysis of AWES Via a Novel Quasi-Analytical Dynamic Model

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Although several models for the power production of AWES are present in the literature, some major physical aspects related to power losses have yet to be definitively understood. In addition to the usual cosine losses associated with elevation, what are its consequences on kite motion? How can the influence of gravity on system performance be assessed? And given a certain trajectory shape, what are the optimal values that parameterize it and how do they change under different conditions?
For this purpose, the work introduces a quasi-analytical dynamic model that provides a more physical insight than a low-fidelity one but is far much simpler than a high-fidelity one. The model informs about the behaviour of significant quantities varying design parameters. Moreover, the system dynamics along the trajectory can be assessed. The main difference from the existing flight path studies is the choice of a cylindrical reference system. It allows a deep comprehension of the physical causes of power losses. In addition, simplicity and suitability for both Fly and Ground-Gen systems with any kite type (rigid or soft) and trajectory shape are peculiarities of the model.

In the model, the flight path shape is prescribed independently before solving the equation of motion [1]. The main assumptions are the point mass representation of the kite, the perpendicularity between the span-wise direction and the relative wind speed, the perfect control (constant C_L and C_D) and the high system glide ratio. In the work, the model is used to analyse the power losses of a Fly-Gen AWES in a circular path shape. Figure 1 shows the efficiency flying the optimal circumference for each different condition which is expressed by the non-dimensional parameters M (from [2]) and G_r (from [1]). The first represents the ratio between centrifugal and lift force. The second expresses the ratio between gravity and centrifugal force and is a function of the wind speed.

The deep understanding of how power losses due to gravity and elevation affect each other, system performance and kite motion as a function of M and G_r is the main outcome of the analysis.

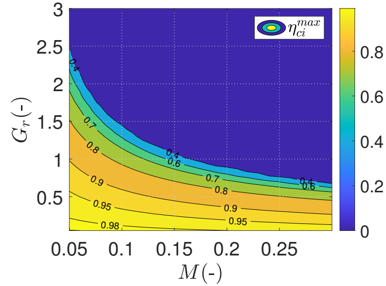

Figure 1: efficiency of a Fly-Gen AWES with the optimal circular flight path (η_{ci}^{max}) for each condition expressed by M and G_r. The blue region represents the conditions for which the kite cannot fly.

References:

[1] Pasquinelli G.: An Engineering Model for Power Generation Estimation of Crosswind Airborne Wind Energy Systems. Master's Thesis, Politecnico di Milano, 2021, `https://doi.org/10.13140/RG.2.2.31882.39363`.

[2] Trevisi F., Gaunaa M., McWilliam M.: The Influence of Tether Sag on Airborne Wind Energy Generation. Journal of Physics Conference Series, 2020.