Abstract for the 8th Energy Colloquium of the Munich School of Engineering "Advances in Energy Transition":

Design Sensitivities of Drag Power Kites

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A drag power kite [1] is a tethered electric aircraft which harvests wind energy by flying in crosswind motions such as figure eights or circles. The kite is like a tip of a rotor blade of a conventional wind turbine. Those blade tips harvest the majority of the energy, because they sweep the largest area and experience the highest (true) airspeed. Similar to the generative braking of the rotor of a conventional wind turbine, the kite brakes generatively, with small onboard wind turbines. Hence, a drag power kite uses only the most effective parts to harvest wind energy. Particularly the tower and the majority of the foundation are replaced by a lightweight tether, with which also higher altitudes with stronger and steadier winds are reachable. Electrical power is transferred between kite and ground via electrical cables integrated in the tether. The kite launches and lands like a multicopter, for which the onboard turbines and generators are reused as propellers and motors. A drag power kite with 600kW nominal power is currently under development at the company Makani/X Development [2].

A challenge is the design of the drag power kite plant. Not only the optimal flight altitude and tether length are obscure, but also many other design variables like the optimal voltage and diameter of the electrical cables in the tether. The latter incorporates e.g. the trade-off between low ohmic loss (large diameter optimal) and low overall aerodynamic tether drag (low diameter optimal). Similarly, a longer tether enables higher flight altitudes with stronger winds, but also increases the aerodynamic drag of the tether as well as the resistance of the electrical cables in the tether.

In this talk, the design sensitivities of an optimized MW-scale drag power kite plant are presented, with surprising and unexpected results. One example is, that the optimal tether voltage is around 7kV, but the optimum is very flat, i.e. the sensitivity is low. Therefore, also a much lower voltage may be used, which may greatly simplify the design of the power electronics at the negligible costs of an overall only slightly off-optimal power plant design. Such sensitivities can be of high value for a kite development team, because investment- and design decisions can be well-substantiated. The presented results are based on a comprehensive and multidisciplinary systems engineering model, which covers dominant effects of all involved disciplines: mechanical engineering (flight dynamics, aerodynamics, materials, structure, and thermodynamics), electrical engineering (power conversions through electrical drives and power electronics, and electricity transmission through tether), control engineering (power curve with actuator limitations, as well as reliability and safety issues due to rotor failures), meteorology (wind resource), and business administration (power plant economics). Preliminary results were presented in [3, 4]. All details on the model derivation, model validation, and results are currently being summarized in the corresponding author's dissertation.

[1] M. L. Loyd. "Crosswind kite power (for large-scale wind power production)". In: Journal of Energy 4.3 (May 1, 1980), pp. 106–111. ISSN: 0146-0412. DOI: 10.2514/3.48021. URL: https://arc.aiaa.org/doi/10.2514/3.48021 (visited on Apr. 19, 2018).
[2] X Development LLC. "Makani". URL: https://x.company/makani/ (visited on Apr. 19, 2018).
[3] F. Bauer, R. M. Kennel, C. M. Hackl, F. Campagnolo, M. Patt, and R. Schmehl. "Drag power kite with very high lift coefficient". In: Renewable Energy (Elsevier) 118.Supplement C (2018), pp. 290–305. ISSN: 0960-1481. DOI: 10.1016/j.renene.2017.10.073. URL: http://www.sciencedirect.com/science/article/pii/S0960148117310285 (visited on Apr. 19, 2018).
[4] F. Bauer, R. M. Kennel, C. M. Hackl, F. Campagnolo, M. Patt, and R. Schmehl. "Power Curve and Design Optimization of Drag Power Kites". In: Book of Abstracts of the Airborne Wind Energy Conference 2017. Ed. by Moriz Diehl, Rachel Leuthold, and Roland Schmehl. Freiburg, Germany: Albert Ludwigs University of Freiburg and Delft University of Technology, 2017, pp. 72–73. ISBN: 978-94-6186-846-6. DOI: 10.4233/uuid:4c361ef1-d2d2-4d14-9868-16541f60edc7. Conference video recording available from: www.awec2017.com (visited on Apr. 19, 2018).

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