Power Curve Analysis Of Airborne Wind Energy Systems

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Power curves are used as a tool to analyze the economic feasibility of wind turbines. Over the years, these power curves have been validated and improved by incorporating on-field data from the already installed wind turbines. Currently, there are very few working prototypes of AWE systems and none of them is a fully functioning commercial unit. Thus, the power curves for AWE systems are still an open topic of discussion in the research community.

In [1], a study is presented discussing a family of power curves of the Enerkite AWE prototype EK30 for different altitudes derived with a focus on motor and structural constraints. In [2], a simplified model is analyzed to estimate the maximum feasible drag power for an on-board production system. In [3], an optimal control problem is discussed which is then used to obtain power curves for a rotary kite AWE system. Limits in power and allowable torque/force have been discussed in [4] for a kite power system in pumping mode.

In the authors' previous work [5], a 6-DOF model for a Magnus-based AWE system validated in simulation environment. In addition, a static model of the production cycle has been presented. Based on this model, we will present a high-level algorithm that gives reel-in speed, reel-out speed, working altitude, and elevation angle, taking into account system saturation. Different ground station structures, including electrical and hydraulic solutions, have been considered.

The resulting power curves consist of different phases where each phase corresponds to different configuration of control variables. They illustrate the high flexibility of on-ground airborne wind energy systems and their potential over conventional wind turbines. On the other hand, this approach can be also used to study the effects of design parameters on the performance.

As authors are working specifically on Magnus-based on-ground AWE systems, numerical application for this type of systems is done to draw comparisons with conventional horizontal axis wind turbines. More details can be found in [6].

References:

[1] Ranneberg, M., Wölfle, D., Bormann, A., Rohde, P., Breipohl, F., Bastigkeit, I.: Fast power curve and yield estimation of pumping airborne wind energy systems. Presented at the AWEC 2017, Freiburg, 15-16 October 2017.

*[2] Bauer, F., Kennel, R.M., Hackl, C.M., Campagnolo, F., Patt, M., Schmehl, R.: Drag power kite with very high lift coefficient. Renewable Energy, **118**, pp. 290–305 (2018). https://doi.org/10.1016/j.renene.2017.10.073*

[3] De Schutter, J., Leuthold, R., Diehl, M.: Optimal control of a rigid-wing rotary kite system for airborne wind energy. Presented at the ECC 2018.

[4] Fechner U., Schmehl R.: Model-Based Efficiency Analysis of Wind Power Conversion by a Pumping Kite Power System. In: Ahrens U., Diehl M., Schmehl R. (eds) Airborne Wind Energy. Green Energy and Technology. Springer, Berlin, Heidelberg, pp 249–269 (2013). https://doi.org/10.1007/978-3-642-39965-7_14

[5] Gupta, Y., Dumon, J., Hably, A.: Modeling and control of a magnus effect based airborne wind energy system in crosswind maneuvers. Presented at the IFAC WC 2017.

[6] Gupta, Y., Dumon, J., Hably, A.: Power curve analysis of on-ground airborne wind energy systems. Presented at the ICIT 2019.