Pumping Kites Wind Farm

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Introduction

Among the Airborne Wind Energy technologies, the pumping kite system (PKS) foresees the use of the traction of a light weight wing to roll out a tether from a drum and convert this motion into electricity. Energy is produced in cycles. When the kite reaches a predefined altitude, it is de-powered and pulled back to its initial position using a fraction of the energy produced before.
Wondering about the large scale deployment of this technology, the Pumping Kites Wind Farm study is done. The main research questions are:

- What is the maximum annual energy that a pumping kite unit can harvest in given wind conditions ?
- What would the design of farm of several unit be ?
- What are the advantages of operate multiple units simultaneously ?
- What is the achievable levelized cost of energy (LCOE) of a farm ?

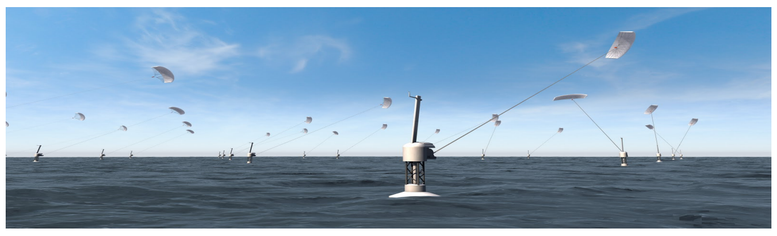
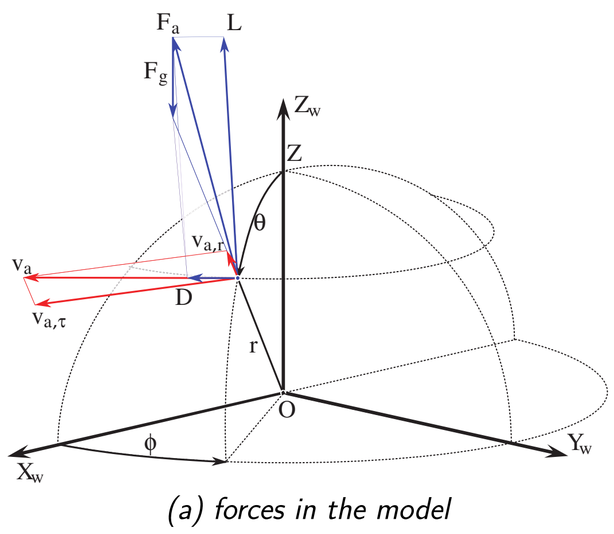


Figure 1: offshore farm concept [1]

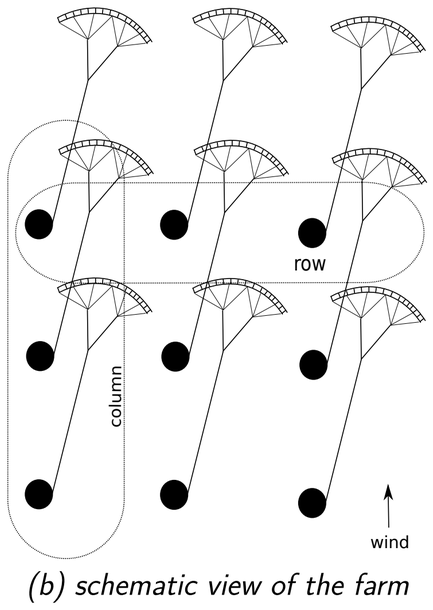
Major companies involved in the topic are attracted from the idea of a farm (Fig. 1). Nevertheless no scientific study has been published.

Methods

The algorithm used to predict the power production of the PKS is based on a quasi-steady model [2]. It is a point mass model. The kite, followed in a spherical coordinate system (Fig. 2a), is assumed to be at every time step in a force equilibrium state.



(a) forces in the model



(b) schematic view of the farm

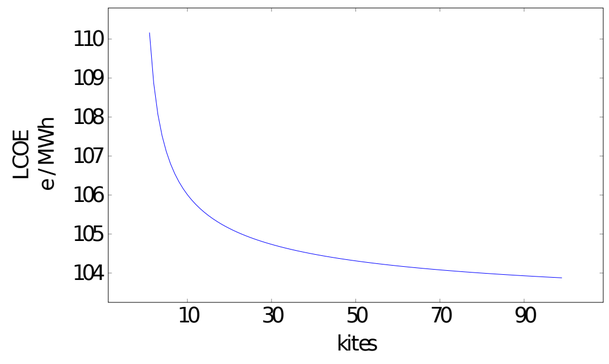
Figure 2: representation of the models used

Taking the same approach of previous studies [3], an optimization on **traction** and **retraction force, minimum and maximum tether length** and **elevation angle** is done for every operating wind speed using a genetic algorithm.
Launch and landing system and efficient and precise control mechanism were assumed to be enough reliable to ensure safe autonomous operation of multiple kites.

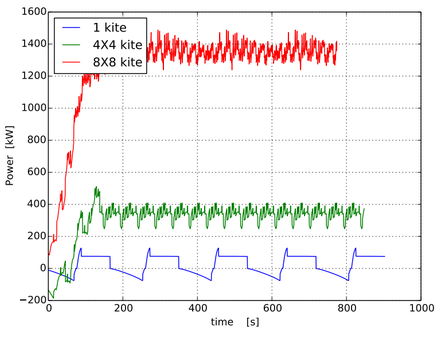
Once the single unit is optimized, it is used to simulate farms of several equal units (Fig. 2b). The design, the operation and the characteristics of the farm are studied and using the LCOE as criterion, the kite optimal surface area is found.

Results

Considering wind conditions of the northern Germany [4], the lowest LCOE is reached by installing 250 m^2 kites. Due to scale effects the LCOE is function of the number of kites in the farm (Fig. 3a).
Having more kites working simultaneously makes the cumulative instantaneous power production of the farm smooth. The graph in Fig. 3b is obtained from the simulation of different sized farms in the same wind conditions.



(a) LCOE



(b) istantaneous power

Figure 3: LCOE and instantaneous power production as function of the number of kites in the farm

Other indicators commonly used in the wind energy industry are computed for comparison with more traditional harvesting methods. The most promising are shown in Tab. 1.

indicator	value
capacity factor	52 %
power per unit land	87.3 W/m^2

Table 1: promising farm performance indicators

Conclusions and Considerations

The study reveals a great potential for the technology. The advantages of using multiple kites simultaneously are both economical and physical. Thanks to a scale effect on costs, the LCOE becomes asymptotically lower while the power production gets more constant.
The object of study are PKS equipped with leading edge inflatable kites. It is plausible that the use of semi-rigid or rigid wings would be even more beneficial both economically and from the control point of view.

References

[1] Skysails, URL http://www.skysails.info/power/power-system/ (2015).
[2] Schmehl R., Noom M., van der Vlugt R.: Traction Power Generation with Tethered Wings. In: *Airborne Wind Energy*, Springer (2013)
[3] C. Grete. *Optimization, Scaling and Economics of Pumping Kite Power Wind Energy*. M.Sc. thesis. Utrecht University (2012)
[4] Fraunhofer IWES. Workshop: Wind Potential for Airborne Wind Systems