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Airborne Wind Energy System (AWES)
Elements for an optimization of an AWES of type flygen

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Introduction

A flygen is a configuration of AWES with generator aloft. The power at the rotor increases with the cube of the apparent wind speed which is several times the value of the real wind speed, and is indirectly linked to the area swept by the kite. Flygen configuration lets high spinning of rotor(s), so small generator(s) and propeller(s),and easier control. Components of FlygenKite are: a Ram kite two lines marketed; a stick carrying the turbine in correct position by patented perpendicular amounts taking the tensile of lines. Applications as demonstrator POC, as toy, as charger for battery of laptop or mobile phone, furthering for utility scale.

Parameters

kA	Kite area, m^2
CL	Lift coefficient
kCD	Drag coefficient ,kite alone
rA	Area swept by the rotor(s), m^2
rD	Drag of rotor (drag coefficient: 8/9)
CD	Global drag coefficient
CL/CD	Kite with rotor, ratio
CL/kCD	Kite alone, ratio
aD	Air density, kg/m^3

Basic rule: small rotors "optimally increase system drag by 50 %" (Diehl's paper,p.8).

Example of a soft kite of type Parafoil:

kA	1.5
CL	1.2
kCD	0.3
rA	0.05
rD	2/45
CD	0.4944
CL/CD	3.64
CL/kCD	4
aD	1.2

Comments:the increase of drag with the rotor in reference is only 9.8765 %.So for the value of 50%,swept area must be 5.0625 times the said rotor (with by far a lower rpm,so more proportional and global weight) .

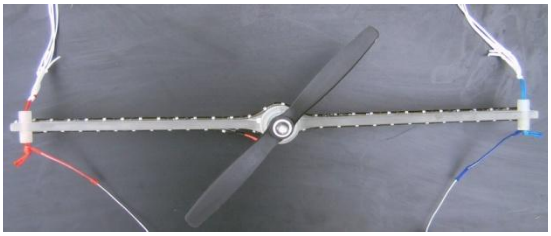
Power: Diehl's formula on Loyd's formula [$P = 2/27\ aD\ A\ w^3\ CL\ (CL/CD)^2$] is given for AWES of type linear (with reel-out and reel-in phases) and works also with AWES of type flygen,but according to the following presentations :$P = 2/27\ aD\ A\ w^3\ CL\ (CL/CD)^2\ (9/8)$ or $= 1/12\ aD\ A\ w^3\ CL\ (CL/CD)^2$. Indeed (9/8) is the inverse number of (8/9) which is the coefficient of drag of an ideal rotor with the maximal value of Betz limit. If we integrate Betz limit on the rotor(s),the complete formula is then: **$P = 4/81\ aD\ A\ w^3\ CL\ (CL/CD)^2$** .

The following examples are given for a value of w (real wind speed) = 6 m/s.
Potential power of the kite in reference: 368.64 W.

Rotor in reference: rA is 0.05 m² and rD is 2/45. CL/CD is 3.64.So kite speed is 21.84 m/s (instead 24 m/s).Power in the rotor: $(21.84)^3\ (1.2)\ (0.05)\ (16/27)/2 = 185.197037$ W.

Now area swept by rotor(s) is 0.253125 m² and rD is 0.225 to reach the optimal value of 50% of the increase of the drag of the kite. CL/CD is 2.6666, that is (2/3) (4).Nor 2/3 is also the amount of slowing down of the wind through a wind turbine according to Betz limit, and is also the optimal speed of a kite for a reel-out system where the corresponding optimal value of roll-out speed is 1/3 wind speed.Power in the rotor(s): $(16)^3\ (1.2)\ (0.253125)\ (16/27)/2 =$ 368.64 W.

Conclusion:
Considering the cost and the weight of rotor(s) for an optimal increase of drag with a kite which ratio is 4,we can prefer a system with only one rotor sweeping 0.1 m².Power in the rotor: $(20.074)^3\ (1.2)\ (0.1)\ (16/27)/2 = 287.6088$ W.
The real power is from 40 % to 50 % of the values indicated above.Indeed there are losses due to not purely crosswind kite motion and some variations of power regarding kite position in the window of flight.These variations are realized by the variations of luminous intensity of the strip led installed on the demonstrator POC which is both a good cheap tool for public information on AWES,investors trying AWES before heavier capital outlay,and searchers.



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