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Airborne Wind Energy Conversion System (AWECS)
Optimization of the AWECS of type flygen with manual piloting : preliminary study

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Introduction

A flygen is a configuration of AWECS with generator aloft. The apparent wind at the kite is very high since figure-8 or loops are realized: 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. If kite speed is 10 times wind speed, power increases by factor of 1000.Flygen configuration lets high spinning of rotor(s), so small generator(s) and propeller. The manual flygen allows to load quickly a battery for laptop or mobile phone, and does not include any electrical cable: so no calculation of (important) losses of conversion is needed.

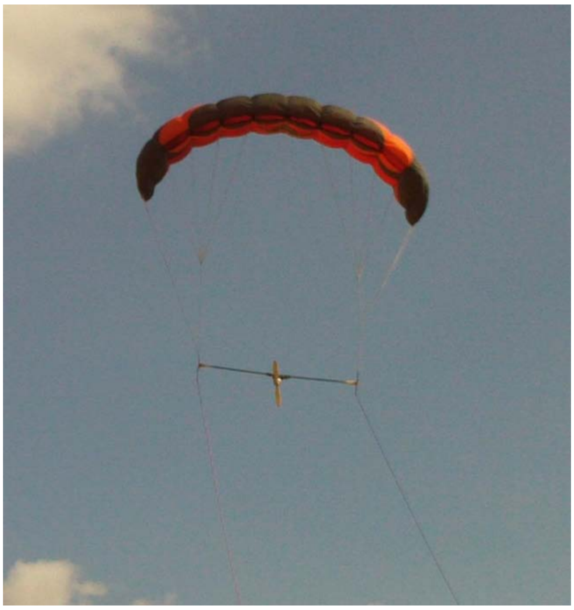
Parameters

kA	Kite area, m²
CL	Lift coefficient
kCD	Drag coefficient ,kite alone
rA	Area swept by the rotor(s), m²
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 AWECS of type linear (with reel-out and reel-in phases) but works also with AWECS 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.

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 two rotors of 0.05 m² each.
Power in the rotors: $(20.074)^3$ (1.2) (0.1) (16/27)/2 = 287.6088 W.

The real power is from 20 % to 80 % of the values indicated above, according to the output of the rotor(s) in respect to the apparent wind speed and the aerodynamic and other losses.

Conclusion: 4 is a low ratio which we find for cheap kites.Semi-rigid or high-performance soft kites will be optimized with a lesser swept area.

References

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