Design of a ground station for a soft wing airborne energy system

September 2024 - January/February 2025

Mots-clefs : Resource-frugal renewable energy, mechatronic design, prototyping, programming (C/C++/python), instrumentation.

1 Abstract

Flying wind turbines are a class of systems for producing renewable energy from wind. However, unlike wind turbines, they also use wind to stay aloft, hence their name [1]. These systems are in the phase of ongoing research and first commercialization [2]. According to a recent white paper for Airborne Wind Europe, flying wind turbines are "a revolutionary solution to access the vast untapped potential of wind resources at heights greater than those accessed by established wind technologies" [3]. Indeed, the absence of a mast makes it easier to capture high altitude winds (300 to 600 m) which are more regular, more powerful and more stable. [4]. Because they **sometimes require up to 90 % fewer materials compared to wind turbines**, these systems can be at least 40 % lower in carbon intensity [3]. To the extent that i) the European Union has set itself a target of 1000 GW of wind production capacity in 2050 [5] and ii) the intensive use of steel, cement and composite materials harms to the carbon footprint of wind turbines and risks slowing down the achievement of these objectives [6], the solution of flying wind turbines seems **essential in the current context of the energy transition**.

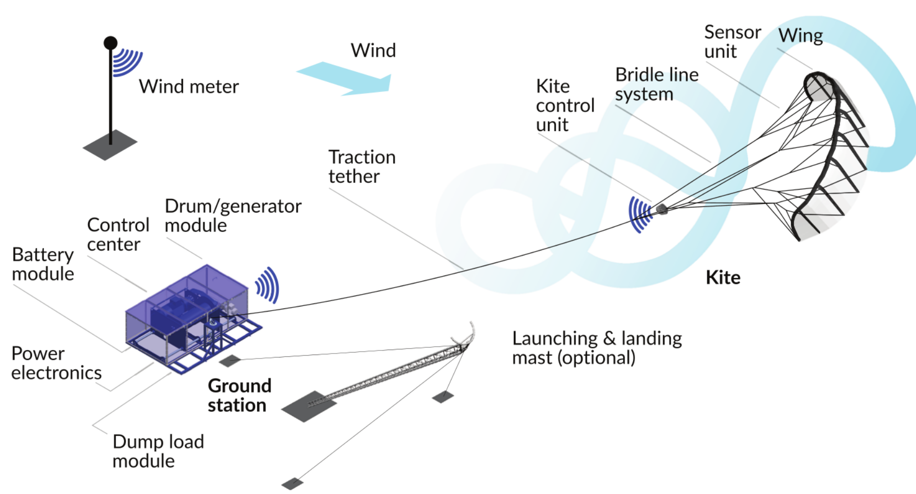

Figure 1: Single-line, ground-generated, flexible sail flying wind turbine system. Image from [7]

The operation of ground generation systems (*ground gen*) is as follows: in a first phase, the sail is pushed by the wind, and follows a figure-of-eight trajectory to maximize its speed, and therefore the force of traction exerted on the cable. By unwinding the cable, the sail drives a generator fixed to the ground, which produces electricity. When the cable is completely unwound, we enter the second phase, the kite is piloted so as to exert a minimum tension and the generator operates as a motor to wind the cable again. The cycle can then start again [1, 8]. For example, Kite Power's "Falcon" system produces 130 kW during the first phase (80% of the time) and consumes 20 kW during the second (20% of the time), i.e. an average production 100 kW [2].

These systems suffer from a **major disadvantage: they are much more difficult to control**. Some systems are already in the first commercialization phase, but the installed control laws lack robustness in the face of the great diversity of operating conditions [8]. Therefore, further research is needed. In particular, there are no open source pilot station plans yet, a real lack for research on these systems. The objective of this internship is to design a communicating, robust, energy-efficient kite piloting station with numerous sensors in order to acquire experimental data. This will make it possible to validate models and formalize the control problem before being able to design new control laws for these systems.

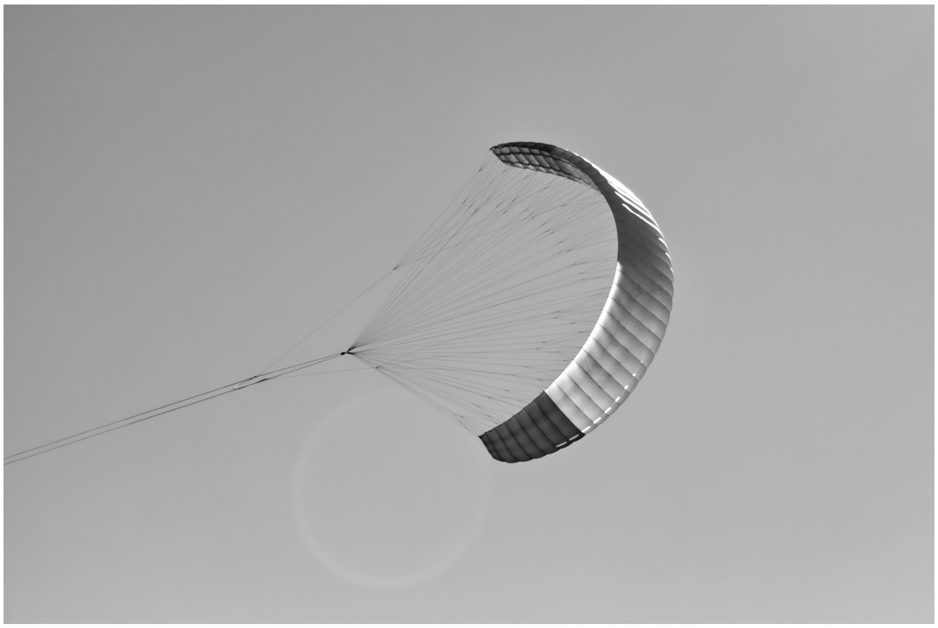

Figure 2: Photograph of a paragliding sail controlled using two cables and a pulley. Kitenergy prototype [9]

The design will be shared as open source and will facilitate theoretical developments in other universities and companies.

This internship follows an end-of-study internship on the design of a sensor box for sailing.

2 Plan of the internship

1. **State of the art:** Initially, the objective is to carry out a state of the art on these systems through bibliographic research and possibly contacting other players in the field (companies, laboratories).

2. **Sizing:** Secondly, the system will be dimensioned by calculating the forces acting on the motors.

3. **Design of an engine bench:** before being able to carry out outdoor tests, it is necessary to test and validate control laws on an engine bench. If the station cannot be designed to also serve as an engine bench, it will be necessary to design a separate bench allowing laboratory experiments.

4. **Design and construction of the station:** During this stage, the motors, electrical circuits constituting the station, batteries, sensors and wires will be chosen. A first rapid prototyping type programming phase will allow initial laboratory tests. A specific study on the station must be carried out with regard to the operating conditions (watertightness, external mechanical stresses) in order to effectively protect the electronics, batteries and electronic cards during the tests.

5. **Design and production of the sail emulation system:** At the same time, a study will be carried out to develop a device to simplify laboratory tests. This study will reflect on the design of a system making it possible to reproduce the behavior of the sail on the lines (characterization bench type hardware emulator in the laboratory).

6. **Experimentation:** Depending on the progress of the course, we will carry out outdoor tests, in order to be able to recover flight data and validate the prototype.

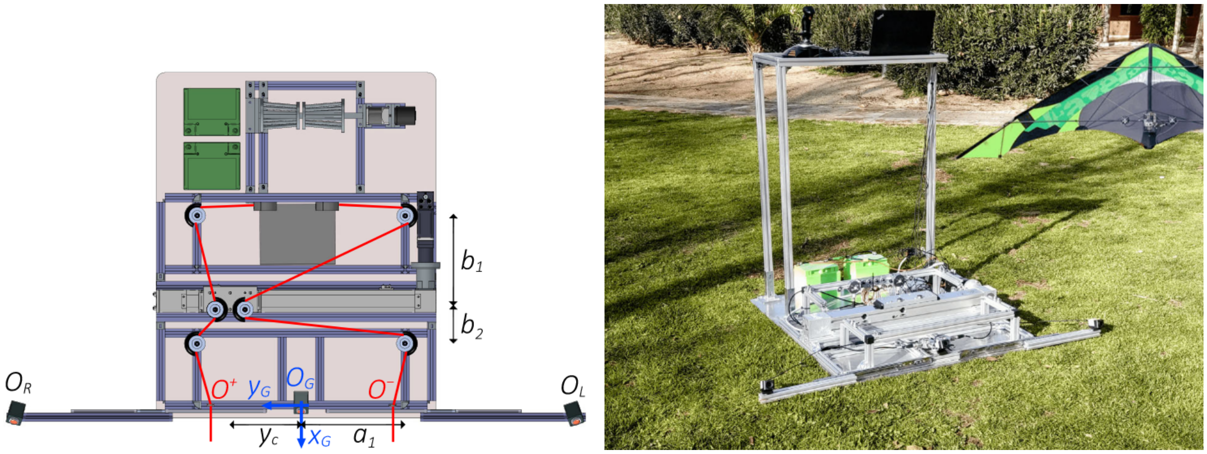

Figure 3: Diagram and photograph of an experimental model. Carlos III University of Madrid prototype [10]

3 Profile of the desired candidate

The candidate will have training in electrical engineering, software engineering or mechatronics, with the desire to explore new themes since the field of flying wind turbines is fundamentally inter-disciplinary. Initial experience in microcontroller programming (STM32 type or other) is required (C/C++). Knowledge of engine control and automation will be appreciated. The work has a strong experimental component.

4 Practical information:

- **Internship location:** Technopôle Diderot, 1 rue Charbillot, 42300, Roanne
- **Dates:** 5 months from September 2024 to January/February 2025 included
- **Salary:** €600 net per month
- **Employer:** Université Claude Bernard Lyon 1

Contacts : Tanguy Simon : `tanguy.simon@univ-lyon1.fr` (LAGEPP Laboratory)

References

[1] C. Vermillion, M. Cobb, L. Fagiano, R. Leuthold, M. Diehl, R. S. Smith, T. A. Wood, S. Rapp, R. Schmehl, D. Olinger, and M. Demetriou, "Electricity in the air: Insights from two decades of advanced control research and experimental flight testing of airborne wind energy systems," *Annual Reviews in Control*, vol. 52, pp. 330–357, Jan. 2021. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S1367578821000109

[2] "Kitepower - Airborne Wind Energy." [Online]. Available: https://thekitepower.com/

[3] B. Associates, "Getting airborne – the need to realise the benefits of airborne wind energy for net zero," Tech. Rep., Sep. 2022. [Online]. Available: https://airbornewindeurope.org/wp-content/uploads/2023/03/BVGA-Getting-Airborne-White-Paper-220929.pdf

[4] U. Zillmann and P. Bechtle, "Emergence and Economic Dimension of Airborne Wind Energy," in *Airborne Wind Energy: Advances in Technology Development and Research*, ser. Green Energy and Technology, R. Schmehl, Ed. Singapore: Springer, 2018, pp. 1–25. [Online]. Available: https://doi.org/10.1007/978-981-10-1947-0_1

[5] "Getting fit for 55 and set for 2050, Electrifying Europe with wind energy," ETIP wind, Wind Europe, Tech. Rep., Jun. 2021. [Online]. Available: https://etipwind.eu/publications/getting-fit-for-55/

[6] A. Farina and A. Anctil, “Material consumption and environmental impact of wind turbines in the USA and globally,” *Resources, Conservation and Recycling*, vol. 176, p. 105938, Jan. 2022. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0921344921005474

[7] V. Salma, F. Friedl, and R. Schmehl, “Improving reliability and safety of airborne wind energy systems,” *Wind Energy*, vol. 23, no. 2, pp. 340–356, 2020, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/we.2433. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/we.2433

[8] L. Fagiano, M. Quack, F. Bauer, L. Carnel, and E. Oland, “Autonomous Airborne Wind Energy Systems: Accomplishments and Challenges,” *Annual Review of Control, Robotics, and Autonomous Systems*, vol. 5, no. 1, pp. 603–631, May 2022. [Online]. Available: https://www.annualreviews.org/doi/10.1146/annurev-control-042820-124658

[9] “Kitenergy - high altitude wind generation.” [Online]. Available: https://kitenrg.com/

[10] I. Castro-Fernández, F. DeLosRíos-Navarrete, R. Borobia-Moreno, M. Fernández-Jiménez, H. García-Cousillas, M. Zas-Bustingorri, A. T. Ghobaissi, F. López-Vega, K. Best, R. Cavallaro, and G. Sánchez-Arriaga, “Automatic testbed with a visual motion tracking system for airborne wind energy applications,” *Wind Energy*, vol. 26, no. 4, pp. 388–401, 2023, _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/we.2805. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/we.2805