Université Claude Bernard Lyon 1

Control and observation on lie groups for airborne wind energy systems

February/March 2025 – July/August 2025

Keywords : Lie groups, automatic control, observer design, resource-frugal renewable energy.

Abstract

Airborne wind energy generators are a class of systems producing renewable energy from the 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]. Considering 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 increases 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**.

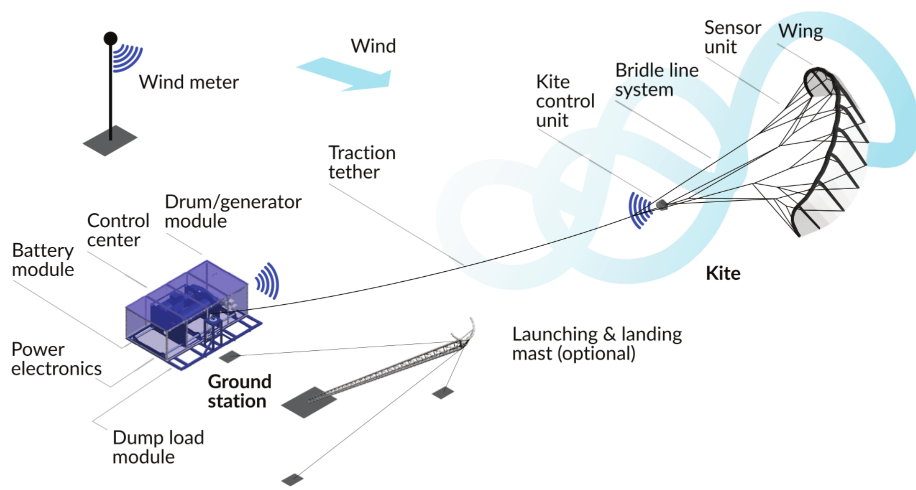

Figure 1: Single-line, ground-generated, flexible sail flying wind turbine system. Image from [7]

These systems suffer from a **major disadvantage: they are much more difficult to control than classical wind turbines**. 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.

These systems can be **modelled using lie algebras**, in particular the Special Orthogonal Lie Group SO(3). The Direct Cosine Matrix (DCM) or rotationless formulations of the SO(3) have been studied in this application [9].

In this internship, we focus on the design of a state observer: an algorithm that will estimate the kite's position and speed using different measurements on the kite : accelerometers (longitudinal accelerations), pitot tubes (apparent airspeed), gyroscopes (angular speeds), load cells (tether force at the kite end) as well as sensors on the ground station: cable angle measurement (azimuth and elevation), see Fig.2 and tether force at the station end (using the motors). The data acquisition is managed by another intern. This internship is focused on modelling and automatic control.

Outline of the internship

1. **State of the art:** carry out a bibliographic research on existing estimation strategies.
2. **Modelling:** Inspired by [10] and [11] (see Fig. 3), model the kite system using the state-space approach
3. **Simulation:** Code a simulator for the kite system on Matlab or Julia.
4. **Problem formulation:** Formulation of the observation problem using classical linear or nonlinear control tools.
5. **Observer:** Design of an observer the kite system and validation in simulation.
6. **Advanced observer:** Improvements in observer design using nonlinear control tools and/or partial derivative equations.
7. **Experimentation:** Depending on the progress of the other internship (design of the prototype), we will carry out outdoor tests on our prototype.

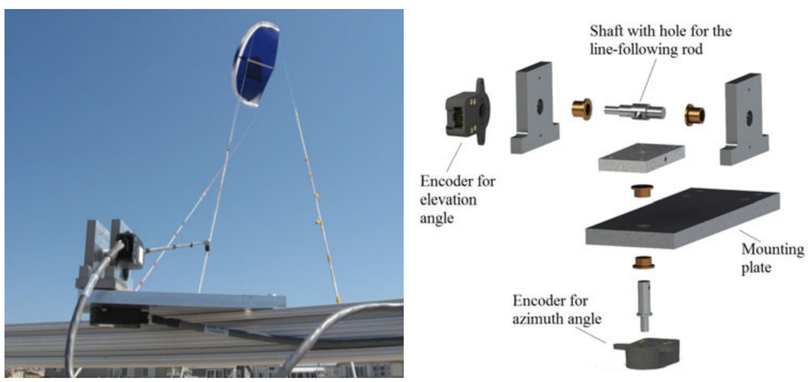

Figure 2: Photograph and diagram of a line angle sensor. [12]

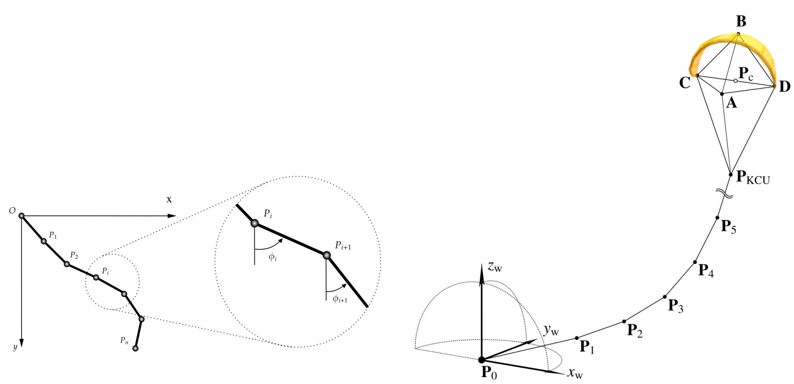

Figure 3: Multibody modelling approach for ropes [10] and kite model from [11]

Profile of the desired candidate

The candidate will have training in automatic control or mathematics, preferably with some prior knowledge on mechanical system modelling. The knowledge of Luenberger observers is required. The ability to code on Matlab and/or Julia is required.

We are looking for candidates whose aim is to pursue this work with a PhD.

Practical information

- **Internship location:** LAGEPP, CPE, 3 rue Victor Grignard, Villeurbanne, France (Lyon)
- **Dates:** 6 months from February/March 2025 to July/September 2025
- **Salary:** approx €650 net per month
- **Employer:** Université Claude Bernard Lyon 1
- **Advisors:** Tanguy Simon (Associate professor, UCBL, LAGEPP), Daniele Astolfi, (Researcher, CNRS, LAGEPP), Ulysse Serres (Associate professor, UCBL, LAGEPP)

Aplication

Please send an email containing your CV and cover letter to T.Simon : `tanguy.simon@univ-lyon1.fr` (LAGEPP Laboratory)

References

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