ANÉMODYNE · LAGEPP · POLYTECH LYON · Université Claude Bernard Lyon 1

Lie Group Modeling and Control of Airborne Wind Energy Systems

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Keywords : Automatic control, modelling, Lie group, experimental testing.

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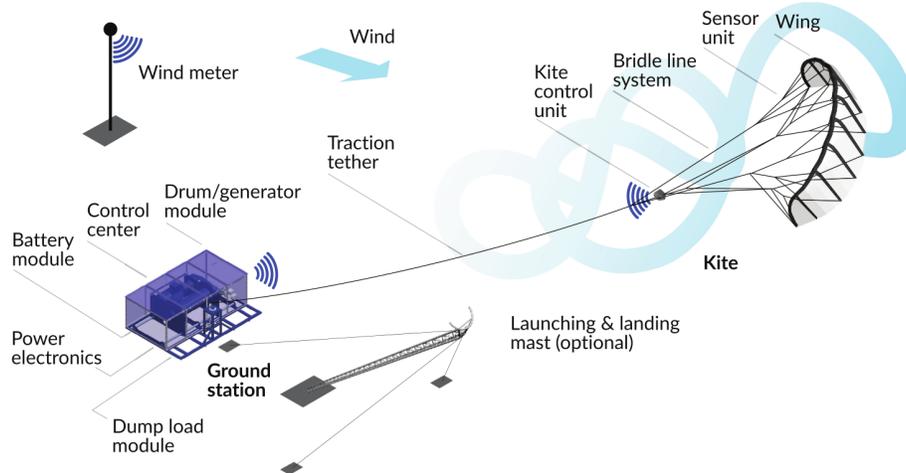
Figure 1: Single-line, ground-generated, flexible sail flying wind turbine system. Image from [7]

This postdoctoral project addresses a central challenge in Airborne Wind Energy (AWE): the persistent gap between theoretical performance predictions and experimental reliability. Bridging this gap requires both more faithful mathematical models and robust control strategies validated on real hardware. This postdoctoral project is part of the Anémodyne project and benefits from the prior work of four students and one technician, two of them worked on the design of a sensor module to be mounted on the kite (containing an inertial measurement unit, force sensors and airspeed sensors), and two on the design of the ground station. The ground station is composed of permanent magnet synchonous machnines as actuators and generators; a spooling systems energised via small DC motors; two microcontrollers and inverters to control the motors, as well as a Raspberry Pi for the centralised control of the station.

The most widely used control-oriented model for AWE systems (AWES) is the point-mass unicycle model, in which the kite is assumed to move along the surface of a sphere, steered by its heading angle. The heading angle is itself controlled by the differential length of the two steering tethers. While computationally convenient, this model has two critical limitations. First, it ignores the reefing line, the line connecting the center of the leading edge to the mast, which provides an additional control input (reel-in or reel-out) and influences the angle of attack through its reel-in speed. Second, the model relies on Euler angles, which are known to suffer from representation singularities. More advanced six-degree-of-freedom (6-DoF) models exist, but none exploit the structure of Lie groups, which are particularly well suited for representing rigid-body motion without singularities and with intrinsic geometric consistency.

The project is structured around three scientific objectives. The first is the derivation of a Lie group formulation of a 6-DoF model that captures the full tether dynamics, both steering and reeling, as well as the aerodynamic effect of the reefing line on the angle of attack. The second objective is the design of a transition-phase control architecture capable of managing under-actuated flight during slack-line states, when tether tension is lost and conventional control authority is reduced. The third objective is the experimental validation of both the theoretical model and the control framework on the LAGEPP AWE platform.

The missions of the postdoctoral researcher include three sequential phases:

- The first phase will focus on model development: deriving the Lie group 6-DoF formulation, incorporating tether and reefing line dynamics, and verifying the model through simulation.

- The second phase will address the control of takeoff and landing, with particular attention to low-wind conditions that produce slack-line states and render the system under-actuated.

- The third phase will be dedicated to experimental validation: the developed control laws will be deployed on the onboard microcontroller infrastructure of the LAGEPP platform, and empirical measurements of power output and flight trajectory will be systematically benchmarked against theoretical predictions.

Candidate Requirements:

- PhD: Automatic Control.

- Specialization: Advanced knowledge of Nonlinear Control.

- Modeling: Experience in system modeling and simulation.

- Hardware: Practical experience with testbench implementation.

Practical information

- **Employer:** Université Claude Bernard Lyon 1

- **Advisors:** Ahmad Hably and Tanguy Simon

Application

Please send an email containing your CV and cover letter to A.Hably : `ahmad.hably@univ-lyon1.fr` (LAGEPP Laboratory)

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