AWE Wind Farm Optimization and Operation

Karanvir Singh Grewal, Alessandro Croce
Department of Aerospace Science and Technology, Politecnico di Milano

Karanvir Singh Grewal

PhD Researcher
Politecnico di Milano
Department of Aerospace Science
and Technology
POLI-Wind Laboratory

Via La Masa 34
20156 Milano
Italy

karanvirsingh.grewal@polimi.it
awetrain.eu/author/karanvir-singh-grewal

Operating multiple airborne wind energy (AWE) systems as a coordinated plant is a key requirement for achieving grid-scale power generation [1]. Increasing plant density (i.e., the number of aircraft per unit area) is essential to improve land-use efficiency and reduce plant-level costs; however, it also introduces significant challenges related to collision avoidance, wake interactions, turbulence, and wind direction variability. These effects can strongly influence both flight trajectories and power production [2]. Unlike conventional wind turbines, AWE systems offer additional degrees of freedom through adaptable flight paths and operating altitudes, creating new opportunities to mitigate adverse flow interactions using plant-level control strategies.

This research focuses on the development of low-fidelity, plant-level simulations for AWE systems operating under dynamic wind conditions and wake interactions. Particular attention is given to understanding wake formation and its evolution from near-field to far-field regions, and to quantifying its impact on downstream kites at varying separation distances. This limiting factor decides upcoming clustering configurations and collision avoidance strategies

Generic plant configurations are used as a testbed to study coordination and control strategies across a range of plant densities, with particular emphasis on collision avoidance and wake-aware operation. Furthermore, siting optimization is applied alongside these regulation strategies to explore feasible plant layouts under varying density and environmental conditions. The overall objective of this research is to establish a modeling and control framework suitable for assessing the operational challenges associated with dense AWE plants and to support future investigations on scalability and reliability.

Conceptual illustration of the research objective: a high-density AWE farm (Author's own illustration, created using AI-based tools).

References:

[1] Fagiano, L., Quack, M., Bauer, F., Carnel, L., and Oland, E.: Autonomous airborne wind energy systems: accomplishments and challenges, Annual Review of Control, Robotics, and Autonomous Systems, 5, 603–631 (2022).

[2] Crismer, J.-B., Trigaux, F., Duponcheel, M., and Winckelmans, G.: Large-Eddy Simulation of airborne wind energy systems wakes, Journal of Physics: Conference Series, 2505, 012036 (2023).

This work has been supported by the AWETRAIN project, which receives funding from the European Union's Horizon Europe research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101168734.