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A Parachute-Based Airborne Wind Energy System and Aerodynamic Characteristics

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High-altitude wind energy has abundant resources, high power densities, and more stable wind direction and speed compared to lower altitudes near the ground. In this work, we proposed an airborne wind energy system (AWES) based on parachutes, which utilizes a cascade of parachutes exploiting aerodynamic drag forces. For this technical approach, the generator is located on the ground, and the parachute-based power kites move upwards under the action of wind forces, driving the tether to pull the motor/generator, converting mechanical energy into electrical energy. After the airborne component ascends to the predetermined height, the power kite is de-powered, and the motor/generator reverses, retracting the kite to the deployment altitude. Currently, we have completed a 2.4MW pilot test in Jixi, Anhui. Such a conceptual design has a high power-to-weight ratio of the aerial components and is easy to scale up (possibly to the order of 10 MW, much greater than the nominal power of other AWES techniques).

The development of this technical approach requires breakthroughs in key technologies such as efficient wind energy capture, efficient energy transmission between air and ground, long-term stable coordinated control, integrated design,and demonstration. In the parachute-based AWES, the shape of the parachute and the distance between neighboring parachutes are key factors affecting the flow field, the aerodynamic drag force, and hence the efficiency in harvesting wind energy. It is conceivable that wake separation induced by the parachute cascade could be a major threat to the efficiency of downstream parachutes. However, due to the limited research in this direction, the wake influence on the whole parachute-based AWES unit remains largely unclear.

To tackle this problem, we numerically investigate the thrust coefficient (Ct) of the parachute cascade with a nominal power of 2.4 MW. The impacts of different states of the parachutes (open or closed) and the distance between neighboring parachutes are quantified. The results clearly manifest a large-scale separation flow that significantly damages the performance of downstream parachutes. It is demonstrated that an increase of the distance of neighboring parachutes (to 1000 m) substantially mitigates the wake effect and enhances the lift force of the whole system.

A parachute-based airborne wind energy system test.