SkyWindFarm: Harnessing High Altitude Wind Power in Scalable Manner

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Wind energy is cubically proportional to wind velocity. As altitude increases, wind velocity not only significantly increases but also becomes more consistent in direction and intensity. However, current airborne wind energy systems (AWES) struggle to harness this stable, untapped resource at scale. SkyWindFarm is the first AWE system capable of harnessing the power of high-altitude winds in a scalable manner. Utilizing vertical axis wind turbines (VAWTs) in a bio-inspired cluster configuration, SkyWindFarm capitalizes on the inherent advantages of VAWTs for airborne applications, such as increased stability and optimal performance in farm configurations. Simulated annealing based CFD optimizations have been conducted to optimize the VAWT cluster, resulting in an overall Cp of 0.47 at TSR 3.0. The system's development has achieved a Technology Readiness Level of 5 through proof-of-concept airborne demonstrations, utilizing a laboratory-scale prototype. Empirical results from wind tunnel testing show a strong alignment (correlation>0.95) with CFD simulations. Further, a transient 6 Degrees of Freedom simulation reveals that SkyWindFarm can reject even the harshest disturbances in approximately 7 seconds. The study comprehensively addresses all major challenges. A comparative cost analysis reveals that SkyWindFarm outperforms current FlyGen AWEs by 25% in efficiency and offers one of the most competitive levelized costs of energy at 25$/MWhr. Furthermore, SkyWindFarm design has the emergent capability for rapid adoption, capable of ramping up power production to the megawatt range. SkyWindFarm is also the first AWE system that can serve as a primary power source, bolstering its value for remote communities and marking a crucial stride toward a sustainable future for all.