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A Roadmap Towards Airborne Wind Energy in the Utility Sector.

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Large-scale commercial implementation of AWES faces a fundamental challenge. Horizontal Axis Wind Turbine (HAWT) manufacturers consistently move towards larger diameters to lower Levelized Cost of Energy (LCoE). Green energy relies less and less on subsidies. AWES' unique selling points will likely be low carbon footprint and access to untapped resources on top of this affordability. Still, AWES must provide competitive LCoE in a very short time, not to be overtaken by a new reality. If they are to take significant share in the energy-mix, multi-megawatt AWES must be developed: large, complex systems, with a capital-intensive development. In going there, commercialization of intermediate sizing can be seen either as a necessary stepping-stone or as a time-consuming distraction. The latter stance favors a development strategy strictly focused on a utility-scale business case. It will drive the architectural choices also for intermediate products in such a way that all invested effort contributes directly to the final goal. For these intermediate products, that are thus not purely optimized for commercialization, more short-term business cases may still be identified. What could those development steps then be? Ampyx Power's AWES uses a rigid-wing aircraft and a ground-based generator [1]. We chose to first make the learning for quality, safety and fully automatic control, through a still relatively small aircraft (AP-3). That eases the expense of manufacturing and risk of early flight testing, leaving only structural upsizing to be tackled next. Our first proposed commercial product AP-4 is sized to be the smallest aircraft that can have competitive LCoE in early business cases (such as repowering), with minimal subsidies. To secure funding for the first series deployment of such a radical innovation, other constraints may apply, e.g. a CAPEX that is already promising. Aiding the AWES case is our finding that a single aircraft design can serve a large range of generators and business cases. This allows for some economy of scale while limiting the overhead in time and money associated to aircraft development.

The result is an AP-4 wing of ~150 m^2 that can be cost-effectively hooked up to any generator between 2 and 3.6 MW. To get significant benefits beyond this combination, the aircraft should be about 50% larger at ~225 m^2 wing area. An aircraft of this size ("AP-5"), combined with a 3-MW generator will annually produce 20% more energy than a 3-MW AP-4, at lower winds and at 10% lower LCoE, and would be altogether more profitable. An AP-5 aircraft with a larger generator, say 5 MW, could unlock the market for floating offshore wind energy with highly competitive LCoE. AP-5 would be the Ampyx Power work horse in the years to come.

In the LCoE-optimal sizing of AP-4 and AP-5, we found that optimal rated power, wing area and cable tension scale virtually proportionally. A key scalability limitation of AWES is that aircraft mass tends to grow faster. Upsizing of utility-scale AWES from generation to generation will be dictated by the rate of innovation enabling the next (near-)proportional scaling step, also for mass. To deliver these innovations is our challenge.

References:

[1] Kruijff M., Ruiterkamp R.: A Roadmap Towards Airborne Wind Energy in the Utility Sector. In: Schmehl R. (eds) Airborne Wind Energy. Green Energy and Technology. Springer, Singapore, pp. 643–662 (2018). https://doi.org/10.1007/978-981-10-1947-0_26