The Value of Airborne Wind Energy in a Zero-Emission Electricity System

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Airborne wind energy system (AWESs) harvest wind energy at high altitudes. In the future, AWE systems might be available at large scale, and part of the electricity generation systems. In order to assess the viability and economical value of AWESs in the power grid, the hourly power production and the related costs are of importance. The potential AWE power production can be estimated with the help of data on the local wind resources, and accurate mathematical models of the AWES. The costs, on the other hand, are hard to determine as no commercial installations exist yet. Alternatively, the marginal system value (MSV) of AWESs can be estimated [1]. The MSV defines the economic value of adding a certain technology to the electricity system.

In order to evaluate the MSV of AWE, first, the annual power generation of AWES is calculated at an hourly resolution for one year. In this study the region of Ireland is chosen. The wind resource is obtained from ERA-5 wind data, available hourly in a 0.25 x 0.25° spatial resolution. The vertical wind shear up to 800 m is obtained from wind speeds at 18 different pressure levels. For a realistic resource potential within a region, inaccessible areas are subtracted. The power production is obtained by an optimal control problem (OCP), that takes the hourly wind speeds as input and computes the average power production of one rigid wing during an optimized flight trajectory. As the OCP computation is time costly, a regression model is trained to map the vertical wind speed components to the computed power output to a high precision. The study is focussed on drag-mode AWESs. Taking into account the percentage of available area, the wind distribution over a wind farm, and efficiency losses due to wake and downtime, a power production potential estimate can be obtained for each grid point.

Further on, the hourly power generation profiles will be implemented into a regional cost-minimizing investment model for power production technologies, presented in [2]. The investment model is set up as a “green field study”, i.e. assuming zero installed capacity and establishing a regional electricity generation system for the year 2050 that meets the hourly demand without emitting CO₂ at minimum cost. The inputs to the model are the regional electricity demand as well as the available renewable resources, storage devices, demand side management and different types of thermal power plants. The output gives the installed capacity per technology, the hourly power dispatch and the minimized annual cost of the electricity system. As a result, the economic value of the AWESs can be estimated based on the change in total annual electricity system costs.

References:
