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Mark Schelbergen

PhD Researcher
Delft University of Technology
Faculty of Aerospace Engineering
Wind Energy Group

Kluyverweg 1
2629 HS Delft
The Netherlands

m.schelbergen@tudelft.nl
kitepower.tudelft.nl

Clustering Wind Profile Shapes to Estimate Airborne Wind Energy Production

Mark Schelbergen[1], Joep Breuer[2], Roland Schmehl[1]
[1]Delft University of Technology
[2]Kitepower B.V.

Airborne Wind Energy (AWE) systems use tethered flying devices to access higher altitudes, typically up to 500 meter, where wind is generally stronger and more persistent. To estimate the Annual Energy Production (AEP) of AWE systems, the wind speed statistics close to the ground are typically extrapolated to higher altitudes, introducing substantial uncertainties. A methodology is developed for characterising a site's wind resource using a set of wind profile shapes. It is demonstrated how this wind resource representation is used together with a performance model to do fast AEP calculations for flexible-kite pumping AWE systems.

The wind profile shapes and corresponding statistics are obtained from the Dutch Offshore Wind Atlas (DOWA) wind dataset. The wind profile shapes do not only describe the change in wind speed with height (wind shear), but also the change in wind direction (wind veer). The Quasi-Steady Model (QSM) of a pumping flexible-kite AWE system as proposed by Van der Vlugt et al. [1] assumes no change in wind direction with height. It is assumed that the kite is continuously steered to correct for the changes in wind direction without penalizing its performance. The QSM is used to specify the mean cycle power output of an AWE system for relevant combinations of wind profile shapes and reference wind speeds at 100 meter height, yielding a power curve for each wind profile shape. The power output is obtained by optimising the mean cycle power over a small set of operational settings [2]. The wind profile shape statistics together with the corresponding power curves are used for estimating the system's AEP.

It is investigated how many wind profile shapes are needed to characterise the wind resource in the fast AEP calculation for the AEP to converge to a steady value. The convergence is studied using a wind resource representation that is obtained specifically for the evaluated location and one that represents a larger area. For the single location representation, the AEP fluctuations are moderate starting from eight wind profile shapes. The multi-location representation is used to evaluate the spatial variability of the AEP over the Netherlands and North Sea.

As a first step in validating the fast AEP calculation, results of the adapted QSM are compared to flight test data of an endurance test campaign of Kitepower's technology demonstrator. This data set allows assessing the modelling accuracy for roughly 1000 pumping cycles and a larger spectrum of wind conditions compared to earlier validation studies [1].

References:

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