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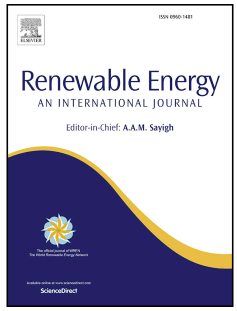

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L. Fagiano, S. Schnez

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On the Take-off of Airborne Wind Energy Systems Based on Rigid Wings

L. Fagiano[a,b,1], S. Schnez[b,1]

[a]*Politecnico di Milano, Dipartimento di Elettronica, Informazione e Bioingegneria*
Piazza Leonardo da Vinci 32, 20133 Milano, Italy
[b]*ABB Switzerland Ltd, Corporate Research*
Segelhofstrasse 1K, CH - 5405 Baden-Dättwil, Switzerland

Abstract

The problem of launching a tethered rigid aircraft for airborne wind energy generation is investigated. Exploiting well-assessed physical principles, an analysis of four different take-off approaches is carried out. The approaches are then compared on the basis of quantitative and qualitative criteria introduced to assess their technical and economic viability. In particular, the additional power required by the take-off functionality is computed and related to the peak mechanical power generated by the system. Moreover, the additionally required on-board mass is estimated, which impacts the cut-in wind speed of the generator. Finally, the approximate ground area required for take-off is also determined. After the theoretical comparison, a deeper study of the concept that is deemed the most viable one, i.e. a linear take-off maneuver combined with on-board propellers, is performed by means of numerical simulations. The simulation results are used to refine the initial analysis and further confirm the viability of the approach.

Keywords: airborne wind energy, renewable energy, wind energy, mechatronic systems, tethered aircraft, autonomous take-off

1. Introduction

The term airborne wind energy (AWE) refers to a class of wind power generators that exploit tethered aircrafts to convert wind energy into electricity [1, 20]. The benefits of AWE systems, compared to traditional wind turbines, are essentially two: lower construction and installation costs and the possibility to reach higher altitudes, where faster and steadier winds blow. According to the current estimates, the combination of these two benefits should render AWE systems competitive with the established energy sources, including fossil fuels [21], in terms of both cost of energy and land occupation. The first papers and patents concerned with AWE appeared in the late 1970s (see e.g. [39, 36]), yet only in recent years a significant and growing research effort has been undertaken by both small companies and universities to develop such concepts via theoretical, numerical and experimental methods [1]. AWE is still at an early development stage and no commercial system exists. However, a relatively well-established set of few different approaches has emerged, while other, less promising ideas have been abandoned.

Today, AWE systems can be classified by the way the lift force that keeps the aircraft airborne is generated – either aerodynamic lift [28, 41, 44, 8, 42, 35], or aerostatic lift [45] – and by the placement of the electrical generators – either on-board of the aircraft [35, 45] or on the ground [28, 41, 8, 44, 42]. Among the systems that exploit aerodynamic lift and generators on ground, a further distinction can be made between concepts that rely on rigid wings [42], similar to gliders, and concepts that employ flexible wings, like power kites [28, 41, 44, 8]. Small-scale prototypes (10-50 kW of rated power) of all the mentioned concepts have been realized and successfully tested to demonstrate their power generation functionalities. Moreover, scientific contributions concerned with several different technical aspects, like the theoretical power yield [36, 4, 5], aerodynamics [10, 11, 9, 17, 34] and controls [31, 12, 6, 15, 23, 18, 27, 47, 14, 48]

Email addresses: lorenzo.fagiano@polimi.it (L. Fagiano), stephan.schnez@ch.abb.com (S. Schnez)
[1]Both authors contributed equally to this publication.