Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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“Optimal Performance of Airborne Wind Energy Systems
subject to realistic Wind Profiles”

Department of Mechanical Engineering

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9:30 A.M.
Remote Defence

Supervisory Committee:
Dr. Curran Crawford, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Brad Buckham, Department of Mechanical Engineering, UVic (Member)
Dr. Adam Monahan, School of Earth and Ocean Sciences, UVic (Outside Member)

External Examiner:
Dr. Mac Gaunaa, Department of Wind Energy, Technical University of Denmark

Chair of Oral Examination:
Dr. Alexandra D’Arcy, Department of Linguistics, UVic

Dr. Stephen Evans, Acting Dean, Faculty of Graduate Studies
Abstract

The objective of this thesis is to assess the optimal power production and flight trajectories of crosswind, on-board airborne wind energy systems (AWES), subject to realistic onshore and offshore, mesoscale-modeled wind data as well as LiDAR wind resource assessment. The investigation ranges from small scale AWES with an aircraft wing area of 10 m² to utility scale systems of 150 m².

In depth knowledge of the wind resource is the basis for the development and deployment of any wind energy generator. Design and investment choices are made based on this information, which determine instantaneous power, annual energy production and cost of electricity. In the case of AWES, many preliminary and current analyses of AWES rely on oversimplified analytical or coarsely resolved wind models, which can not represent the complex wind regime within the lower-troposphere. Furthermore, commonly used, simplified steady state models do not accurately predict AWES power production, which is intrinsically linked to the aircraft’s flight dynamics, as the AWES never reaches a steady state over the course of a power cycle. Therefore, leading to false assumption and unrealistic predictions. In this work, we try to expand our knowledge of the wind resource at altitudes beyond the commonly investigated lowest hundreds of meters. The so derived horizontal wind velocity profiles are then implemented in to an optimal control framework to compute power-optimal, dynamically feasible flight trajectories that satisfy operation constraints and structural system limitations. The so derived trajectories describe an ideal, or at least a local optimum, and not necessarily realistic solution. It is unlikely that such power generation can be reached in practice, given that disturbances, model assumptions, misalignment with the wind direction, control limitations and estimation errors, will reduce actual performance.

We first analyze wind light detection and ranging (LiDAR) measurements at a potential onshore AWES deployment site in northern Germany. To complement these measurements we generate and analyzed onshore and offshore, mesoscale weather research and forecasting (WRF) simulations. Using observation nudging, we assimilate onshore LiDAR measurements into the WRF model, to improve wind resource assessment. We implement representative onshore and offshore wind velocity profiles into the awebox optimization framework to derive power-optimal trajectories and estimate AWES power curves. Based on a simplified scaling law, we explore the design space and set mass targets for small to utility-scale, ground-generation, crosswind AWESs.