University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Master of Applied Science

of

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BEng (Hefei University of Technology, 2016)

"Path-following Control for Power Generating Kites Using Economic Model Predictive Control Approach"

Department of Mechanical Engineering

Wednesday, May 15, 2019
2:00 P.M.
Engineering Office Wing
Room 430

Supervisory Committee:
Dr. Yang Shi, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Keivan Ahmadi, Department of Mechanical Engineering, UVic (Member)

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Dr. Timothy Iles, Department of Pacific and Asian Studies, UVic

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Abstract

Exploiting high altitude wind energy using power kites is an emerging topic in the field of renewable energy. The claimed advantages of power kites over traditional wind power technologies are the lower construction costs, less land occupation and more importantly, the possibility of efficiently harvesting wind energy at high altitudes, where more dense and steady wind power exists. One of the most challenging issues to bring the power kite concept to real industrialization is the controller design. While traditional wind turbines can be inherently stabilized, the airborne nature of kites causes a strong instability of the systems. This thesis aims to develop a novel economic model predictive path-following control (EMPFC) framework to tackle the path-following control of power kites, as well as provide insightful stability analysis of the proposed control scheme.

Chapter 3 is focused on the stability analysis of EMPFC. We proceed with a sampled-data EMPC scheme for set-point stabilization problems. An extended definition of dissipativity is introduced for continuous-time systems, followed by giving sufficient stability conditions. Then, the EMPFC scheme for output path-following problems is proposed. Sufficient conditions that guarantee the convergence of the system to the optimal operation on the reference path are derived. Finally, an example of a 2-DoF robot is given. The simulation results show that under the proposed EMPFC scheme, the robot can follow along the reference path in forward direction

with enhanced economic performance, and finally converges to its optimal steady state. In Chapter 4, the proposed EMPFC scheme is applied to a challenging nonlinear kite model. By introducing additional degrees of freedom in the zero-error manifold (i.e., the space where the output error is zero), a relaxation of the optimal operation is achieved. The effectiveness of the proposed control scheme is shown in two aspects. For a static reference path, the generated power is increased while the kite is stabilized in the neighborhood of the reference path. For a dynamic reference path, the economic performance can be further enhanced since parameters for the reference path are treated as additional optimization variables. The proposed EMPFC achieves the integration of path optimization and path-following, resulting in a better economic performance for the closed-loop system. Simulation results are given to show the effectiveness of the proposed control scheme. Finally, Chapter 5 concludes the thesis and future research topics are discussed.