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

of

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MASc (University of British Columbia, 2015)
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“Multi-scale Transactive Control In Interconnected Bulk Power Systems Under High Renewable Energy Supply and High Demand Response Scenarios”

Department of Mechanical Engineering

Wednesday, November 15, 2017
9:00 A.M.
Clearihue Building
Room B007

Supervisory Committee:
Dr. Ned Djilali, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Yang Shi, Department of Mechanical Engineering, UVic (Member)
Dr. Panajotis Agathoklis, Department of Electrical and Computer Engineering, UVic (Outside Member)

External Examiner:
Dr. Mohammad Shahidehpour, Department of Electrical and Computer Engineering, Illinois Institute of Technology

Chair of Oral Examination:
Dr. Eric Sager, Department of History, UVic

Dr. David Capson, Dean, Faculty of Graduate Studies
Abstract

This thesis presents the design, analysis, and validation of a hierarchical transactive control system that engages demand response resources to enhance the integration of renewable electricity generation resources. This control system joins energy, capacity and regulation markets together in a unified homeostatic and economically efficient electricity operation that increases total surplus while improving reliability and decreasing carbon emissions from fossil-based generation resources.

The work encompasses: (1) the derivation of a short-term demand response model suitable for transactive control systems and its validation with field demonstration data; (2) an aggregate load model that enables effective control of large populations of thermal loads using a new type of thermostat (discrete time with zero deadband); (3) a methodology for optimally controlling response to frequency deviations while tracking schedule area exports in areas that have high penetration of both intermittent renewable resources and fast-acting demand response; and (4) the development of a system-wide (continental interconnection) scale strategy for optimal power trajectory and resource dispatch based on a shift from primarily energy cost-based approach to a primarily ramping cost-based one.

The results show that multi-layer transactive control systems can be constructed, will enhance renewable resource utilization, and will operate in a coordinated manner with bulk power systems that include both regions with and without organized power markets. Estimates of Western Electric Coordinating Council (WECC) system cost savings under target renewable energy generation levels resulting from the proposed system exceed US$150B annually by the year 2024, when compared to the existing control system.