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 (Zhejiang University City College, 2014)

"Modelling, Design and Energy Management of a Hybrid Electric Ship – A Case Study"

Department of Mechanical Engineering

Wednesday, April 22, 2020
9:30 A.M.
Remote Defence

Supervisory Committee:
Dr. Zuomin Dong, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Peter Oshkai, Department of Mechanical Engineering, UVic (Member)

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Dr. Merrie Klazak, School of Music, UVic

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Abstract

The widely-used passenger and car ferries, sailing regularly and carrying heavy loads, form a unique type of marine vessel, providing vital transportation links to the coastal regions. Modern ferry ships usually are equipped with multiple diesel engines as prime movers. These diesel engines consume a large amount of marine diesel fuel with high fuel costs, and high emissions of greenhouse gas (GHG) and other harmful air pollutants, including CO2, HC, NOx, SO2, CO, and PM. To reduce fuel costs and the harmful emissions, the marine industry and ferry service providers have been seeking for clean ship propulsion solutions.

In this work, the model based design (MBD) and optimization methodology for developing advanced electrified vehicles (EV) are applied to the modelling, design and control optimizations of clean marine vessels with a hybrid electric propulsion system. The research focuses on the design and optimization of the hybrid electric ship propulsion system and uses an open deck passenger and car ferry, the MV Tachek, operated by the British Columbia Ferry Services Inc. Canada, as a test case. At present, the ferry runs on the Quadra Island – Cortes Island route in British Columbia, Canada, with dynamically changing ocean conditions in different seasons over a year.

The research first introduces the ship operation profile, using statistical ferry operation data collected from the ferry's voyage data recorder and a data acquisition system that is specially designed and installed in this research. The ship operation profile model with ship power demand, travelling velocity and sailing route then serves as the design and control requirements of the hybrid electric marine propulsion system. The development of optimal power control and energy management strategies and the optimization of the powertrain architecture and key powertrain component sizes of the ship propulsion system are then carried out. Both of the series and parallel hybrid electric propulsion architectures have been studied. The sizes of crucial powertrain components, including the diesel engine and battery energy storage system (ESS), are optimized to achieve the best system energy efficiency. The optimal power control and

energy management strategies are optimized using dynamic programming (DP) over a complete ferry sailing trip.

The predicted energy efficiency and emission reduction improvements of the proposed new ship with the optimized hybrid propulsion system are compared with those of two benchmark vessels to demonstrate the benefits of the new design methodology and the optimized hybrid electric ship propulsion system design. These two benchmarks include a conventional ferry with the old diesel-mechanical propulsion system, and the Power Take In (PTI) hybrid electric propulsion systems installed on the MV Tachek at present. The simulation results using the integrated ship propulsion system model showed that the newly proposed hybrid electric ship could have 17.41% fuel saving over the conventional diesel-mechanical ship, and 22.98% fuel saving over the present MV Tachek. The proposed optimized hybrid electric propulsion system, combining the advantages of diesel-electric, pure electric, and mechanical propulsions, presented considerably improved energy efficiency and emissions reduction. The research forms the foundation for future hybrid electric ferry design and development.