TRENT HILLIARD

BEng (Mechanical), Dalhousie University 2010
MASc (Mechanical), Dalhousie University 2012

DEPARTMENT OF MECHANICAL ENGINEERING

TITLE OF THESIS:	WHOLE BUILDING MODEL PREDICTIVE CONTROL WITH OPTIMIZATION FOR HVAC SYSTEMS UTILIZING SURFACE LEVEL WEATHER FORECASTS
TIME/DATE:	2:00 pm, Monday, August 14, 2017
PLACE:	Room 3107, Mona Campbell Building, 1459 LeMarchant Street, Halifax NS

EXAMINING COMMITTEE:

Dr. Carey Simonson, Department of Mechanical Engineering, University of Saskatchewan (External Examiner)

Dr. Mark Gibson, Department of Civil & Resource Engineering, Dalhousie University (Reader)

Dr. V. Ismet Ugursal, Department of Mechanical Engineering, Dalhousie University (Reader)

Dr. Lukas Swan, Department of Mechanical Engineering, Dalhousie University (Supervisor)

DEPARTMENTAL REPRESENTATIVE:	Dr. Dominic Groulx, Department of Mechanical Engineering, Dalhousie University
CHAIR:	Dr. Malcolm Heywood, PhD Defence Panel, Faculty of Graduate Studies

ABSTRACT

The commercial and institutional sector of the building stock present a significant portion of energy consumption within Canada, and of that the majority is used for space conditioning. In order to meet reduction in greenhouse gas emission targets to combat climate change as outlined in the Paris Agreement, a reduction in energy use is required. Due to the expectations of a comfortable workspace (and salaries outweighing operational costs of a building), technological changes are needed to reduce energy consumption. While many new technologies being developed are more efficient than existing HVAC solutions, they are often costly to retrofit into the existing building stock. One solution is to use the existing equipment in the building more efficiently through the use of advanced control algorithms that account for upcoming conditions, such as weather and occupancy. This form of predictive control can realize savings that are not possible when using reactive, or rule based control that is the current industry norm.

This dissertation creates a new model predictive control (MPC) method for application to an institutional building using advanced surface level weather forecasts and multi-tiered implementation strategy. A simulation platform was created to test and evaluate various control strategies, followed by an experimental implementation at the operating building. A whole building optimization was conducted, with the surface level climatic forecasts used to ensure occupant comfort was maintained, via zone operative temperature, throughout the building zones. The simulation results show a reduction in total energy use of 2-3% (5-6% HVAC energy) annually, while the experimental results show a savings of 29% of HVAC electricity and 63% of steam. Experimental results outperform the simulation results due to real building inefficiencies not captured in the simulation model benchmark assumptions.

The research contributions of this dissertation include: i) the implementation of zone operative temperature as a whole building comfort variable, ii) the usage of surface level weather forecasts for predictive control, iii) the usage of various models and objective functions to achieve improved energy and cost performance, iv) the introduction of emulated model predictive control for both model validation and for the morning start optimization of MPC, and v) the use of a randomForest regression model for buildings.