

# Control of air conditioning systems with Carrier Corporation and Modelon

## Introduction

These Master Thesis topic is a collaboration between the Department of Automatic Control, Modelon and Carrier Corporation. The intent is to obtain problem formulations and reduced order models for the optimal control of HVAC equipment that captures operating constraints and performance targets and evaluates model characteristics, workflows and different tool environments.

## Carrier Corporation Background and Importance of Control

Carrier Corporation is one of the world's largest provider of building technologies. Its fire safety, security, building automation, heating, ventilation, air conditioning and refrigeration systems and services promote integrated, high performance buildings that are safer, smarter and sustainable.

Building systems, and HVAC systems in particular, are dynamic by nature. In addition, this type of equipment is subject to a number of hard constraints in operation due mainly to the protection of components including the compressor. This project will carry out trade studies to evaluate elements of a control design workflow that combines steady state information for set point determination and dynamic information for protection of the equipment and dynamic performance optimization.

## Modelon Background

Modelon provides software solutions and expert services to organizations that use model-based simulation tools to design and develop technical systems. Modelon's libraries, solver, and deployment solutions are leading products available in the market today for modeling, simulation and optimization. Our products enable companies to focus on delivering a unified picture of product system interaction and performance – from product concept to operation.

Modelon is an industry leader in model-based systems engineering with a goal of advancing open-standard technologies, allowing customers to leverage their tools of choice and share models throughout the product development cycle. Today, we serve a clientele base across a wide range of industry sectors which include some of the largest companies in the world.

## Project 1: Model Reduction Based on Balanced Truncation

Modelica is a language for building dynamical models of physical objects. Modelica has its roots in Lund and is now widely used in industry (<https://www.modelica.org>). The models obtained are typically high fidelity descriptions but they are often too complicated for control design because of a large number of states and nonlinearities. To design controllers the models are linearized at an operating point Modelica has facilities for linearization and the models can be simplified using a technique called balanced truncation (<https://se.mathworks.com/help/control/ug/balanced-truncation-model-reduction.html>). The goal of the project is



to develop a collection of programs that can deliver reduced order models of different complexity starting from a given Modelica model. The steps are to pick an operating point, use Modelica to generate a linearized model around the operating point and to generate a range of simpler models using balanced reduction. The results should be tested on Carrier chiller for air conditioning.

The work will be done at Modelon with Kristian Tuszynski at Carrier ([kristian.tuszynski@carrier.com@carrier.com](mailto:kristian.tuszynski@carrier.com@carrier.com)), Johan Åkesson ([johan.akesson@modelon.com](mailto:johan.akesson@modelon.com)), Magdalena Atlevi ([magdalena.atlevi@modelon.com](mailto:magdalena.atlevi@modelon.com)) and Karl Johan Åström at LTH ([kja@control.lth.se](mailto:kja@control.lth.se)) will serve as supervisors. Please submit your application to [student@modelon.com](mailto:student@modelon.com).

## Project 2: Model Reduction Based on System Identification

Modelica is a language for building dynamical models of physical objects. Modelica has its roots in Lund and is now widely used in industry (<https://www.modelica.org>). The models obtained are typically high fidelity descriptions but they are often too complicated for control design because of a large number of states and nonlinearities. Simpler models can be obtained by using system identification techniques where the control variables are perturbed and the responses are observed. To obtain good results it is important that the process is properly excited by the control signals. Relay autotuning followed by a chirp signal (swept sinusoidal) is a convenient way to generate input signals, see [http://www.control.lth.se/publications/show/autotuner-identification-of-tito-systems-using-a-single-relay-feedback-experiment\(bae99949-f1ec-48a9-aedf-48c6d7e2a154\)\(publication\)/](http://www.control.lth.se/publications/show/autotuner-identification-of-tito-systems-using-a-single-relay-feedback-experiment(bae99949-f1ec-48a9-aedf-48c6d7e2a154)(publication)/) and the MS project Björk och Levenhammar Relay Auto-tuners in Modelica (<https://lup.lub.lu.se/student-papers/search/publication/8915999>). The project should develop the methods so that models of first and second order with time delays can be generated automatically from simulations of complex Modelica models and test them on a Carrier chiller for air conditioning.

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## Project 3: Assessment of Control Strategies for Chillers

There are many ways to design a control system if process models are available, from simple PID controllers to control laws based on optimization based techniques such as Linear Quadratic Control and Model Predictive Control. The purpose of this thesis project is to explore design controllers for a chiller that operates over a wide range starting with an assessment of the problem: how complex controllers are needed based on system statics and dynamics, performance, robustness and process safety and progressing with a selection of control design techniques. The work will be based on control of a chiller which is a multi-variable system, with strict system safety requirements (avoid compressor stall). The assessment can start with an analysis of the static gain matrices for different operating conditions to find couplings and design of decoupled PID controllers with selectors to guarantee safety, design of multi-variable controllers based on model predictive controllers and comparison of the controllers.

The work will be done at Modelon in Lund with Kristian Tuszynski at Carrier ([kristian.tuszynski@carrier.com@carrier.com](mailto:kristian.tuszynski@carrier.com@carrier.com)) Johan Åkesson ([johan.akesson@modelon.com](mailto:johan.akesson@modelon.com)), Magdalena Atlevi ([magdalena.atlevi@modelon.com](mailto:magdalena.atlevi@modelon.com)) and Karl Johan Åström at LTH ([kja@control.lth.se](mailto:kja@control.lth.se)) will serve as supervisors. Please submit your application to [student@modelon.com](mailto:student@modelon.com).

