

# On the issue of model predictive control for solar thermal cooling systems

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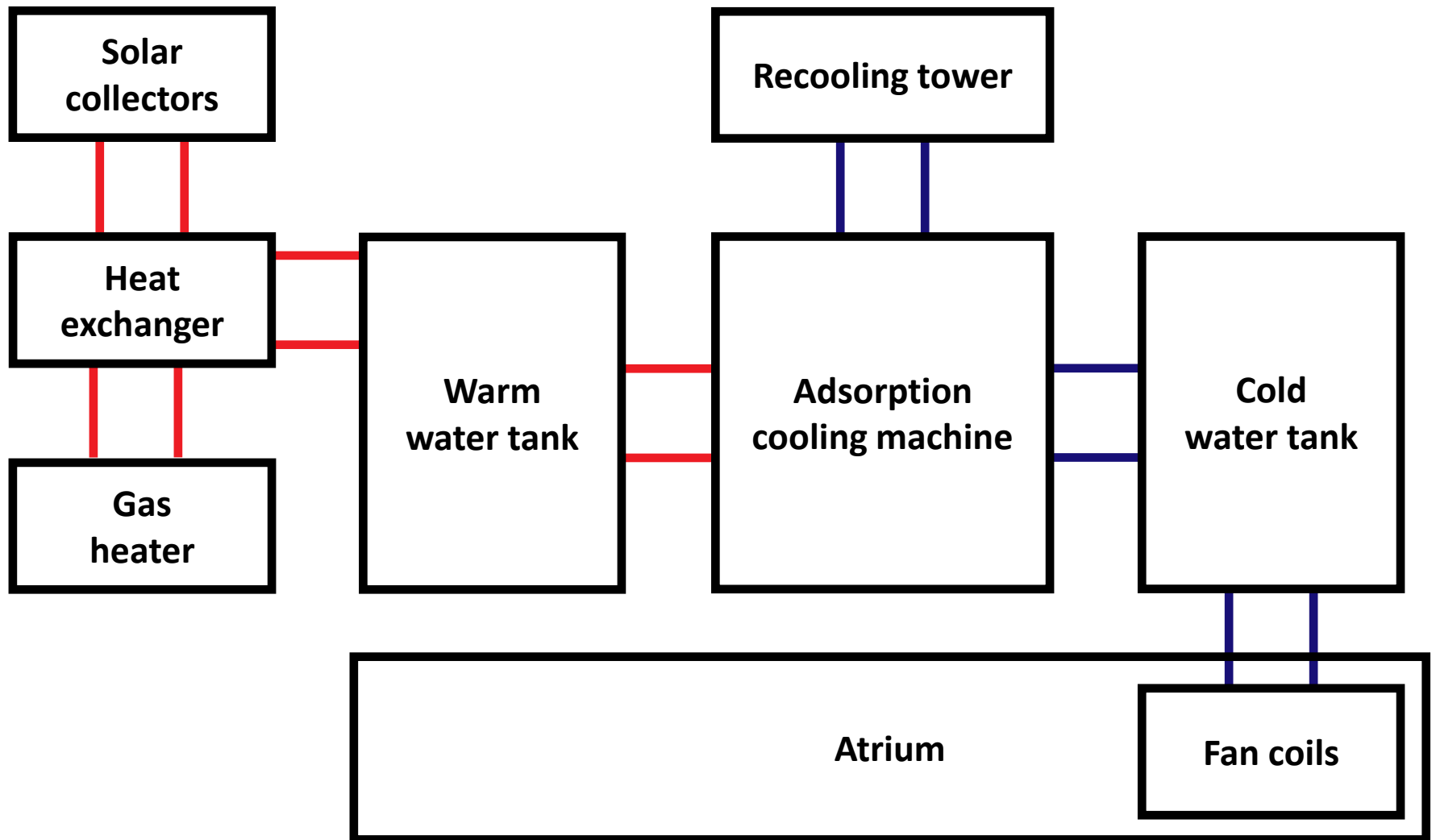
Workshop on Optimal Control of  
Thermal Systems in Buildings using Modelica

University of Freiburg, March 24<sup>th</sup>, 2015

- **Talk will focus on current status of my PhD project**
  - “Model predictive control for solar thermal cooling systems”, started in November 2014
- **Contents**
  - Aim of the PhD project
  - Description of the system setup
  - General framework
  - Work packages and related issues

- **Design and implementation of a physical model**
- **for optimal control**
- **of the solar thermal cooling system under construction at the faculty building of the Faculty of Management Science and Engineering at Karlsruhe University of Applied Sciences**
- **with model predictive control**

# Description of the system setup



- **Modelling:** Modelica
- **Optimization:** CasADi<sup>1</sup>
- **Optimality:** minimum use of non-renewable energy
- **Forecast data:** e. g. weather data, estimated number of people, ...
- **Conditions:** e. g. pleasant room conditions, technical restrictions, ...

<sup>1</sup> Andersson, Joel: A General-Purpose Software Framework for Dynamic Optimization. Dissertation, Faculty of Engineering Science, KU Leuven, 2013.

- 1. Building a global, physical system model in Modelica**
- 2. Provide (most) automatic model transfer from Modelica to a format suitable for CasADi**
- 3. Parameter estimation within the CasADi environment**
- 4. Defining and solving the optimal control problem (OCP) within the CasADi environment**
- 5. Online-optimization of the solar thermal cooling system**

- **Build first physical system model using TIL<sup>1</sup>-library**
  - sophisticated thermal components library for Modelica, including media databases
  - support by TU Braunschweig / TLK Thermo GmbH
  - but, the model will be not directly suitable for optimization
  
- **Build second, optimization-suitable, physical model displaying the most important system effects**
  - identify with help of TIL-model
  - modelling without discontinuous expressions etc.

<sup>1</sup> TLK Thermo GmbH: TIL-Suite – Simulates Thermal Systems, <http://www.tlk-thermo.com/en/software-products/til.html>, last visited March 11<sup>th</sup>, 2015

- **Emerging issues in modelling**
  - how to efficiently identify the important effects?
  - how to model the air mass inside the atrium adequately, minding the optimization intent (speed, memory)?
  - optimization-suitable computation of media data (e. g. spline interpolation) means huge effort, so transfer to external C(++) libraries, or are there better approaches?
  - ... can one completely avoid discontinuous expressions without over-simplifying the system's interrelationships?



- **Model transfer using the JModelica<sup>1</sup> compiler**
  - enables transfer of restructured, optimization-suitable model for further use within the CasADi environment
  - allows formulations of parameter estimation and optimal control problems via Optimica<sup>2</sup> solved using CasADi
- **Emerging issues in model transfer**
  - will all necessary expressions be supported?
  - how to transfer the included media libraries?

<sup>1</sup>Åkesson, Johan: Languages and Tools for Optimization of Large-Scale Systems. PhD thesis, Department of Automatic Control, Lund University, 2007.

<sup>2</sup>Åkesson, Johan: Optimica – An Extension of Modelica Supporting Dynamic Optimization, Department of Automatic Control, Lund University, 2008.

- **JModelica ships parameter estimation functionalities**
  - formulate e. g. using Optimica
  - though, e. g. methods for direct further investigation of estimation results necessary
- **Possible, useful/necessary extensions**
  - automatic computation of the covariance matrix and confidence intervals of the estimated parameters
  - ...

- **Define and solve the OCP for NMPC within the CasADi environment**
  - keep temperature within appropriate boundaries
  - use measurement data
  - use forecast data
- **Emerging issues**
  - acquisition of forecast data and adequate consideration of the available data within the controller
  - ...

- **Automatically feed the optimal control inputs to the system**
  - cooling system is controlled by a central controlling unit
  - not completely clear yet how to interface the controller correctly
  
- **Emerging issues**
  - possible speed and memory issues to be considered when choosing the platform for the NMPC controller
  - interface problems
  - ...

**Thank you for your attention!**