Optimal Control of Thermal Systems in Buildings using Modelica

Workshop Freiburg
March 23-24, 2015

Lieve Helsen
Thermal System Simulation (The Sysi)
KU Leuven - EnergyVille
Two-day workshop (31 participants, 27 talks)
Initiative by University of Freiburg and University of Leuven

Aim:
Bring together researchers from different disciplines, create interaction and synergy

Focus:
Optimal Control of Thermal Systems in Buildings using Modelica
WELCOME

Program (low budget, tight schedule):
• Joint lunches, Joint diner (self-payment)
• Sessions (session chairs):
  o Introduction of participants
  o Modelling of thermal systems in Modelica
  o Possibilities for optimization within the scope of Modelica
  o Control and Control models
  o MPC – application to Modelica models
  o Grid interaction optimization
  o Closing (take-home messages)
WELCOME

Time for individual conversation and discussions

- Long coffee breaks
- Lunches
- Diner
- Interactive session (day 2)

Organizing committee in Freiburg: thank you!

- Moritz Diehl
- Adrian Bürger
- Christine Paasch
WELCOME

Focus
Optimal Control
Thermal Systems in Buildings
Modelica

Source: Roel De Coninck
THERMAL SYSTEMS IN BUILDINGS

CONTEXT
Smart grids
Flexibility
Renewable energy sources
Energy efficiency
Energy storage
Zero GHG emission
NZEB

⇒ Integrated System Approach
⇒ Optimal Control

Different worlds meet each other:
- Mechanical engineering
- Civil engineering
- Electrical engineering
- Control engineering
- Chemical engineering
- Material engineering
THERMAL SYSTEMS IN BUILDINGS

Challenges: Complex and multi-disciplinary systems
Access to parameters, identification data
Accuracy versus complexity
Interaction/integration design - control
Model validation (emulator, controller model)
Simple but accurate controller models
Mixed continuous – discrete control
Non-linearities
Large range of time constants
Uncertainties
...

KU LEUVEN
THERMAL SYSTEMS IN BUILDINGS

Simulation framework: emulator
- Sufficiently accurate with all interactions accounted for
- Neighbourhood or district level: electricity grid
- Stochastic occupant behaviour profiles

Integrated District Energy Assessment by Simulation
MODELICA library - IDEAS

Integrating the dynamics of the hydronic, thermal as well as electrical energy systems and networks at both the building and aggregated level within a single model and solver.

Source: Roel De Coninck, PhD, 2015
THERMAL SYSTEMS IN BUILDINGS

Simulation framework: emulator

Source: Ruben Baetens
Simulation framework Modelica

- Modelica allows for linear, non-linear and hybrid model formulations
- Modelica can handle multi-domain and stiff models and is equation-based
- Modelica has a connector concept to support component-based modelling
- The object-oriented philosophy stimulates model reuse, and is well suited for library development

Source: Roel De Coninck, PhD, 2015
THERMAL SYSTEMS IN BUILDINGS

Simulation framework – Modelica Libraries

- IDEAS (KU Leuven)
- Buildings (LNLB)
- AixLib (RWTH Aachen)
- ...

Converge towards Annex 60 Library

THERMAL SYSTEMS IN BUILDINGS

Simulation framework: controller models
- Reduced order models
- White/grey/black box
- Model identification (= optimization)
- Modelling and system identification are the most difficult and time-consuming parts of the automation process

Grey-box Toolbox
FastBuildings Library

Source: Roel De Coninck, PhD, 2015
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Simulation framework: workflow

- Automation of the simulation workflow, including pre- and post-processing of simulations

Python modules

- awesim: simulation management
- ModelicaRes: workflow automation (including Simdex from awesim)

Source: Roel De Coninck, PhD, 2015
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Optimization framework

- Within the modelica environment (JModelica.org)
- Coupling with other tools
QUESTIONS

How to connect Modelica based simulation tools with state-of-the-art optimization tools?

Which problem formulations make sense?
Introduction of participants
Towards optimal design and control through the study of component and global system dynamic behavior

Technical expertise:

- **Simulation**: from detailed emulator models to reduced controller models (object oriented modeling, system identification)
- **Optimization and Control**: optimal design, open and closed loop control, rule based control, model based (predictive) control, robust control
- **Experiment**: from lab-scale to pilot plant and field tests
THE SYSI TEAM

Lieve Helsen, Alessia Arteconi, Ercan Atam, Arnout Aertgeerts, Roel De Coninck, Damien Picard, Stefan Antonov, Anouk Bosmans, Dieter Patteeuw, Filip Jorissen, Mats Vande Cavey, Bram van der Heijde

KULLOCS: Maarten Sourbron, Brecht Baeten, Joachim Verhelst

Alumni: Frederic Cuypers, Joan Govaerts, Clara Verhelst, Jan Hoogmartens, Shivanand Wasan