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

WELCOME

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):
  - Introduction of participants
  - Modelling of thermal systems in Modelica
  - Possibilities for optimization within the scope of Modelica
  - Control and Control models
  - MPC – application to Modelica models
  - Grid interaction optimization
  - Closing (take-home messages)

WELCOME

Time for individual conversation and discussions

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

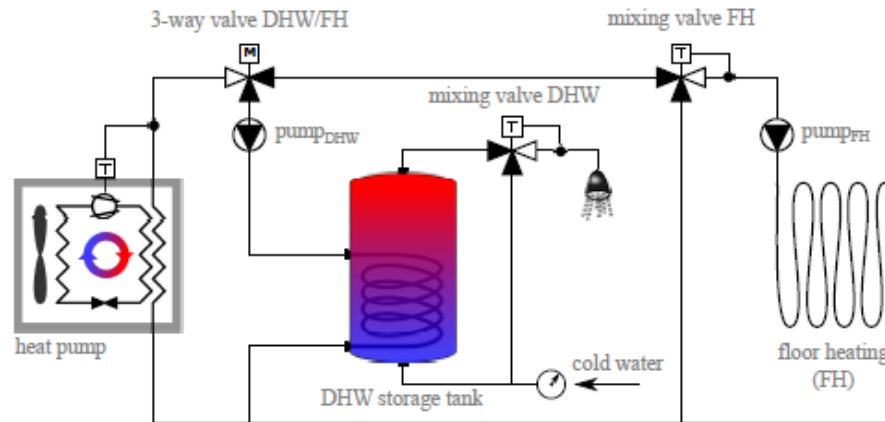**Organizing committee in Freiburg: thank you!**

- Moritz Diehl
- Adrian Bürger
- Christine Paasch

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WELCOME

Focus

Optimal Control
Thermal Systems in Buildings
Modelica

Source: Roel De Coninck

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THERMAL SYSTEMS IN BUILDINGS

CONTEXT

Smart grids

Flexibility

Renewable energy sources

Energy efficiency

Energy storage

Zero GHG emission

NZEB

...

$\Rightarrow$ Integrated System Approach

$\Rightarrow$ Optimal Control

Different worlds meet each other:
- Mechanical engineering
- Civil engineering
- Electrical engineering
- Control engineering
- Chemical engineering
- Material engineering

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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

...

THERMAL SYSTEMS IN BUILDINGS

Simulation framework: emulator

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

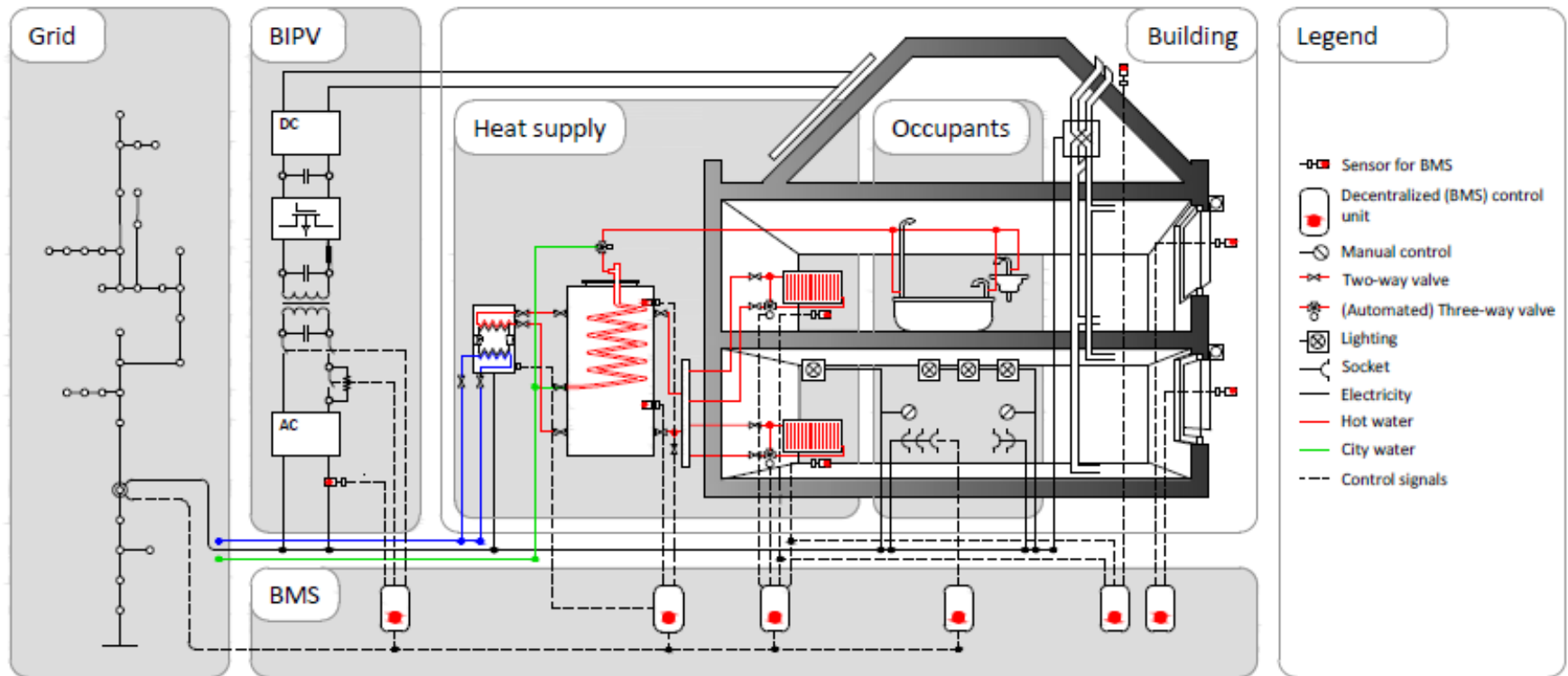**Integrated District Energy Assessment by Simulation MODELICA library - IDEAS**

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

Source: Roel De Coninck, PhD, 2015

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THERMAL SYSTEMS IN BUILDINGS

Simulation framework: emulator

Source: Ruben Baetens

THERMAL SYSTEMS IN BUILDINGS

Simulation framework Modelica

o   Modelica allows for linear, non-linear and hybrid model formulations

o   Modelica can handle multi-domain and stiff models and is equation-based

o   Modelica has a *connector* concept to support component-based modelling

o   The object-oriented philosophy stimulates model reuse, and is well suited for library development

Source: Roel De Coninck, PhD, 2015

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THERMAL SYSTEMS IN BUILDINGS

Simulation framework – Modelica Libraries

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

➡ Converge towards Annex 60 Library

IEA-EBC-Annex 60 (2013-2017) 'New generation computational tools for building and community energy systems based on the Modelica and Functional Mockup Interface standards'

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THERMAL SYSTEMS IN BUILDINGS

Simulation framework: controller models

- o Reduced order models

- o White/<u>grey</u>/black box

- o Model identification (= optimization)

- o Modelling and system identification are the most difficult and time-consuming parts of the automation process

Grey-box Toolbox

FastBuildings Library

Model F

Source: Roel De Coninck, PhD, 2015

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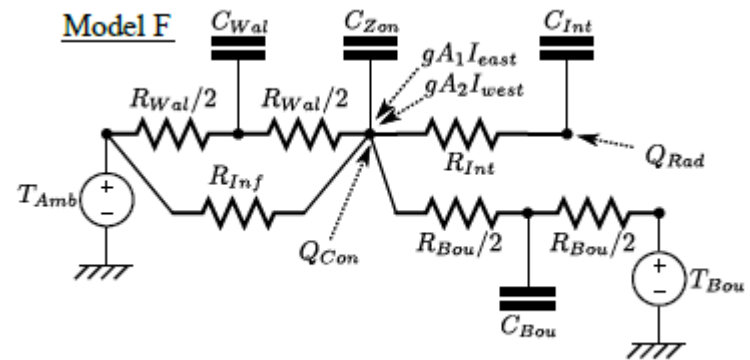
THERMAL SYSTEMS IN BUILDINGS

Simulation framework: workflow

o 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

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

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QUESTIONS

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

Which problem formulations make sense?

Introduction of participants

THE SYSI TEAM – Lieve Helsen et al

Towards optimal design and control through the study of component and global system dynamic behavior

Technical expertise:

- o **Simulation:** from detailed emulator models to reduced controller models (object oriented modeling, system identification)

- o **Optimization and Control:** optimal design, open and closed loop control, rule based control, model based (predictive) control, robust control

- o **Experiment:** from lab-scale to pilot plant and field tests

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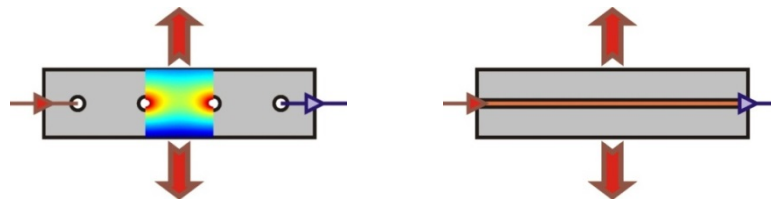
THE SYSI TEAM

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
<u>KULLOCS</u>: Maarten Sourbron, Brecht Baeten, Joachim Verhelst

<u>Alumni</u>: Frederic Cuypers, Joan Govaerts, Clara Verhelst, Jan Hoogmartens, Shivanand Wasan

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