SIMULATION IN PRE- AND POST DESIGN

Week 8

7LY3M0
Building performance and energy systems simulation

Where innovation starts
Simulation in the Building Life-cycle

- Most typical: after the design phase, for code compliance
- Eventually during the design phase, for decision making
new Generation building
ENERGY SIMulation tools

Scientific School
24 to 28 October 2016
Porticcio, Corsica (France)
Simulation has applicability beyond building design

Source: Michael Wetter
Simulation has applicability beyond building design

Source: Michael Wetter
PART I: Pre-design

Product development

Development of simplified models

Government policy target setting
Product innovations – Valley of Death

Universities
1. Observation of basic principles
2. Concept development and testing
3. Proof of concept
4. Technology validation in lab
5. Technology validation in operation
6. Technology demonstration in operation
7. System demonstration in real world
8. System complete and qualified

Industry
9. Actual proof of real-world system operation
Product development

» Start from lab-scale prototype

» Support decision-making and identify potential areas for improvement
  – Which properties/characteristics should be changed?
  – Focus on promising markets

» Quantify potential performance improvement for typical buildings using virtual experiments

» Identify future development directions
Example – smart energy glass

![Smart energy glass examples](image)

![Building example](image)

![Graph showing relative performance gains](image)

- Total energy savings
- Useful daylight illuminance
- Glare discomfort
- Overheating hours
Example – smart energy glass
Example – smart energy glass
Example: low infrared absorptivity coating

[Diagram showing energy flow and energy consumption comparison between normal and improved IR reflectivity options.]
Product development
Lumiduct
Lumiduct
Lumiduct

LUMIDUCT

- Direct radiation
- Diffuse radiation
- Electricity
Lumiduct

» Heating, cooling and lighting energy demand
» Daylight illuminance (UDI)
» Glare reduction (DGP)
» View to outside
» Electricity generation
» Thermal energy inside double skin
Lumiduct

SketchUp

Material properties, Sensor grid

BSDF files (.XML)

WINDOW 7.4

Latitude, Longitude, DNI, DHI, Time of year

Light dimming

Type DLT

State

Control $T_{\text{air}} /$ illuminance

New state

Type 56

Weather data
Product development challenges

» Lack of information about the product
  – How do we simulate something that does not exist yet?
  – How to keep up with ever-changing product iterations?

» How to adapt current programs to simulate future products?
  – Creative modeling approaches and/or source code modifications are often necessary

» How to match simulation output with interests of R&D team
Development of simplified models

» State of the art models
  – Detailed complex models
  – Require high expertise, computationally expensive
  – In some situations, simpler models are more appropriate

» Use state-of-the-art models to produce/calibrate/validate a user-friendly and/or computationally inexpensive model

» Applications
  – Regulatory purposes
  – Building control
  – Early design, commercial purposes, …
Example: Simplified model for Brazilian energy regulation

Solar Chimney sizing tool

\[ Q_{\text{harvest}} = +0.345 \cdot \text{glazed area (MWh/year)} \]

[Hensen, J. L. M., Costola, D., & Trcka, M. 2012, Earth, Wind and Fire project. Final report - activities carried out by the computational building performance simulation group, ]
Simplified models challenges

» Define scope and goals of the model
  – Assumptions regarding the input, uncertainty

» Define the necessary accuracy for the model
  – Simple enough, but not too simple

» Managing large dataset, automate simulations

» Statistical analysis
Government policy target setting

» Evaluation of certain measures on the whole building stock
  – In-depth knowledge about the current situation
  – Assessment of different scenarios/policies

– Subsidies, incentives, cash-back
– Legislation, taxes, penalties
Climate change adaptation for the Dutch housing stock
Government policy target setting – challenges

» Proper information about the building stock

» Role of occupant behavior

» Managing large dataset, automate simulations, statistical analysis

» Robustness of solutions/conclusions
  – “political pressure”
  – legal implications

» Synthesis of results, recommendations
Simulation has applicability beyond building design

Source: Michael Wetter
PART II: Post-design

Operational performance

Calibration

Model predictive control
Simulation has applicability beyond building design

Source: Michael Wetter
A commissioned ship is one deemed ready for service. Before being awarded this title, however, a ship must pass several milestones. Equipment is installed and tested, problems are identified and corrected, and the prospective crew is extensively trained. A commissioned ship is one whose materials, systems, and staff have successfully completed a thorough quality assurance process.
» Is performed specifically to ensure building operation in accordance with design intent and construction documents.

» Building commissioning is a systematic and designed process coordinated by a commissioning authority or team.

» Includes documentation, verification procedures, functional performance tests, validation, and training.
BLC – Stakeholders/Stages

- Building Use
- Building Control Strategies
- Operation Objectives

DESIGN

COMMISSIONING
Building operation strategy

- Decided at design
- Seldom monitored and modified during operation

**BAS/BMS**
- Designed for system control and actuation
- Interactive GUI with changing set points capabilities

- Few tools are available to the on-site engineer to evaluate possible new strategies

- Utility Bills
- Received Complaints

(user feedback)
Operational performance overview

**Benchmarks**

Performance data from other buildings with similar characteristics

**Baselines**

Energy performance assessment of the building being analyzed

**Predictions/estimations**

Energy efficiency measures applied to a virtual model of the building
Operational performance overview

Benchmarks

Performance data from other buildings with similar characteristics

Sources: Public/Private building portfolio databases

- Senternovem
- Green guide 19 (UK Offices)
- HOPE (Buildings survey 1990)
- DOE (DB online)
- CBECS (EnergyStar 4645 buildings)
Operational performance overview

Baselines
(a.k.a. longitudinal benchmarks)

• Historical data analyzed
• Consumption trends (signatures)
• Evolution of the operation performance

Energy performance assessment of the building being analyzed

KPI’s

DATA ACQUISITION
(Measurement Framework)
Operational performance overview

• Energy Conservation measures (ECM)
• Model based Control
• FDD
• Ideal operation performance

Predictions/estimations

Energy efficiency measures applied to a virtual model of the building
Simulation calibration

» Often required: use of calibrated simulation models
  – Recall: design simulations and measured energy consumption can vary greatly

Simulation calibration

» Often required: use of calibrated simulation models
  – Recall: design simulations and measured energy consumption can vary greatly

» Calibrated: the difference between the simulated and measured consumption reduced to within a previously defined tolerance level

» How is simulation calibrated?
  – First, data screening/processing
  – Daily data covering a period ≥3 months, preferably more
  – Vary input parameters within reason until consumption difference within tolerance
  – Iterative process
Calibration barriers

Barriers to BES Calibration

- Standards
- Expense
- Complexity
- Inputs
- Controls
- Faults
- Uncertainty
- Identification
- Integration
- Automation

Simulation calibration methodologies

» Ad-hoc calibration procedure
  – Not systematic, range of inputs highly subjective
  – Not explicitly evidence based

» Characteristic signature method
  – Characteristic signatures - plots showing effect of change in single input parameter on simulation outputs
  – Calibration signatures - plots showing the relationship between simulated and measured energy consumption
  – Compare signatures to identify inputs to modify to reach calibration
Example: TU/e spectrum building
Calibration procedure

1. Initial comparison
2. Characteristic signatures
3. Systematic trial-and-error
Calibration procedure
Integrated room automation

» Integrated control of:
  – Heating
  – Cooling
  – Ventilation
  – Electric lighting
  – Solar shading

» Hot summer day: Control mode REJECT
» Cold winter day: Control mode COLLECT
» Mid-season day: Control model ???
Model predictive control (MPC) for buildings
Model predictive control (MPC) for buildings

Six representative building/location cases:

![Graph showing the relationship between additional NRPE use in % of PB use and amount of comfort violations [Kh/a]. The graph compares SMPC and RBC cases.](http://www.opticontrol.ethz.ch/)
Model predictive control (MPC) for buildings
Open issues - MPC

» Simulation speed vs. accuracy of results
  – Optimization in real-time

» Weather data projections and uncertainty
  – Wrong forecast, wrong decision?

» Integration: BMS, sensors, actuators and simulation tool
Some conclusions

» The use of modeling and simulation during building operation is rare

» A well-calibrated building model is a useful resource

» Short term usage:
  – Commissioning of systems
  – Energy conservation measures
  – Fault detection and diagnostics
  – Model predictive control

» Long-term: can be used as a reference against which to compare energy performance: dynamic benchmarking
Simulation has applicability beyond building design

- Computation accelerates R&D for new products
- Model-based design of experiments
- Validate models and extrapolate
- Real experiments at User Facility
- Scoping Studies
- Computation during building life cycle
- Preliminary design
- Detailed Design
- Control & FDD
- Commissioning
- Embedded systems to support operation
- new products deployed to market

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Theory assignments

Submit
12/09 19/09 26/09 03/10 10/10 17/10 24/10 31/10

Peer-review

7LY3M0 - Building performance and energy systems simulation
## Follow-up meetings

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Time</th>
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<tr>
<td>Tuesday</td>
<td>1 Nov</td>
<td>8h45 – 10h30</td>
<td>VRT 7.06, VRT 8.06</td>
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<tr>
<td>Friday</td>
<td>4 Nov</td>
<td>13h30 – 15h30</td>
<td>VRT 8.06, VRT 9.06</td>
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<tr>
<td>Tuesday</td>
<td>8 Nov</td>
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