Saving Energy by Improved Building Control

- D. Gyalistras, A. Fischlin – Terrestrial Systems Ecology, ETH Zurich, Switzerland
- M. Morari, C.N. Jones, F. Oldewurtel, A. Parisio – Automatic Control Laboratory, ETH Zurich, Switzerland
- T. Frank, S. Carl, V. Dorer, B. Lehmann, K. Wirth – Building Technologies Laboratory, EMPA Dübendorf, Switzerland
- P. Steiner, F. Schubiger, V. Stauch – Federal Institute for Meteorology and Climatology MeteoSwiss, Zurich, Switzerland
- J. Tödtli, C. Gähler, M. Gwerder – Building Technologies Division, Siemens Switzerland Ltd, Zug, Switzerland

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich · EMPA Materials Science & Technology · Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra MeteoSwiss · SIEMENS · ccem.ch · swisselectric research

Introduction

Buildings use ~40% of final energy worldwide.

- What can be gained thanks to improved control?
- How important is predictive control?

Focus of present work: Integrated Room Automation.

Potential benefit of predictive control: more optimal use of cheap control actions (e.g. blinds positioning, free cooling); exploitation of the building's thermal storage capacity.

Approach

1. Determine Performance Bound (**PB**) = lowest possible energy use for a given system, cost function, and set of comfort requirements.
2. Compare with reference control strategies, e.g.
   – Short Term Optimal Control (**STOC**),
   – Rule Based Control (**RBC**).

Methods & Data

- Annual Primary Energy (**PE**) consumption estimated by means of whole-year, hourly time step simulations with a single-zone dynamic building model.
- Office Buildings: Thermal insulation levels "Passive House", "Swiss Average"; Construction types "light", "heavy"; Internal gains levels "low", "high"; Window area fractions 30%, 80%; Façade orientations N/E/S/W and SW (corner).
- Hourly observations of: global radiation on vertical orientations of the building, outside air temperature, wet-bulb temperature; 9 European SYNOP sites for the year 2006.
- Automated Building Systems

Automated Building Systems	*S1*	*S2*	*S3*	*S4*
Blinds	x	x	x	x
Electric lighting	x	x	x	x
Mech. ventilation flow, heating, cooling	–	x	x	x
Mech. ventilation energy recovery	–	x	x	x
Natural ventilation (night-time only)	–	–	–	x
Cooled ceiling (capillary tube system)	x	x	–	–
Free cooling with wet cooling tower	x	x	–	–
Radiator heating	x	x	–	–
Floor heating	–	–	–	x

- Heat production: earth coupled heat pump; Cold production: mechanical compression chiller.
- Outside air temperature dependent thermal comfort range (Winter: 21-25 °C; Summer: 22-27 °C).
- Standard occupancy and ventilation schedules.
- PB: Estimated with the aid of a Model Predictive Control (MPC) procedure assuming perfect building model plus perfect weather and internal gains forecasts, optimization horizon H = 72 h.
- STOC: MPC with perfect building model and H = 1h.
- RBC: Non-predictive, variants "basic" and "advanced".

Results

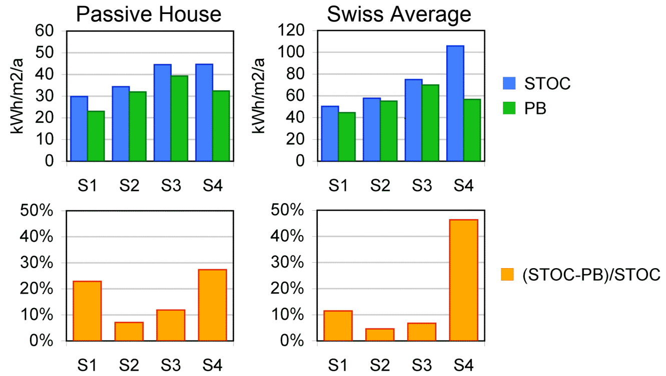

Fig. 1: Comparison of annual PE consumption of the STOC strategy with the PB (*top*), and maximum achievable annual PE savings for the STOC strategy (*bottom*) for systems *S1* to *S4*. Each bar gives the average from 96 building cases (light/heavy, low/high, 30%/80%, N/E/S/W; sites Geneva, Basel and Lugano).

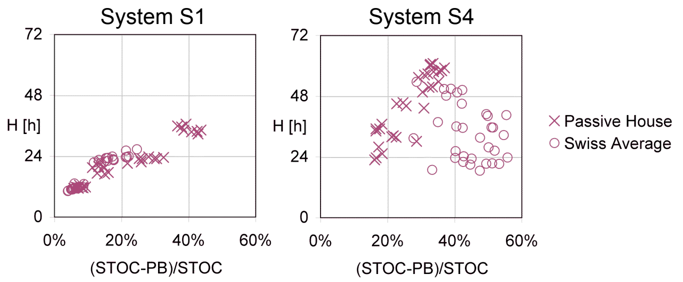

Fig. 2: Required prediction horizon (H) to approach the PB to within 1% as a function of STOC maximum achievable PE savings. Each cross or circle refers to one of 32 building cases (light/heavy, low/high, 30%/80%, N/E/S/W) and gives the average for sites Geneva, Basel and Lugano.

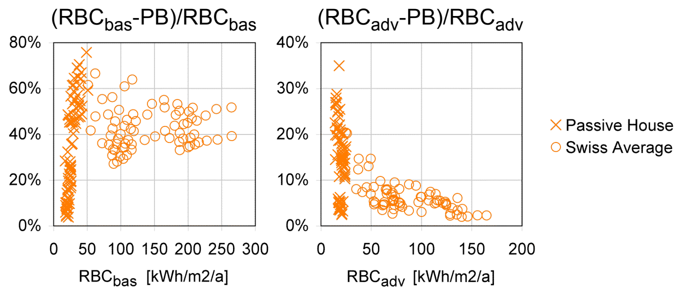

Fig. 3: Overview of maximum achievable annual PE savings for the two RBC strategies, System *S1*, façade orientation SW (corner). Each cross or circle refers to one of 8 building cases (light/heavy, low/high, 30%/80%) at one of 9 European sites.

Conclusions

- Demonstration of significant savings potential.
- Potential is highly system and case dependent.
- It can be partially exploited by improved non-predictive control.
- Cases with large required prediction horizons suggest that improvement might only be possible by means of predictive control.

Further information: http://www.opticontrol.ethz.ch/