Facts of the project

Project duration:	May 2007 – July 2010
Support «swisselectric research»:	SFr. 905 000.–
Partner:	Competence Centre Energy and Mobility CCEM-CH
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Use of Weather and Occupancy Forecasts for Optimal Building Climate Control

OptiControl

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Abstract

The project dealt with the development of predictive control solutions in order to reduce the energy usage of buildings, improve occupant comfort, and reduce peak electricity demand. The focus was on the automated optimal control of blinds, electric lighting, heating, cooling, and ventilation in individual building zones. Project results were: software, models and data sets for the simulation-based assessment of building control; new algorithms for improved weather predictions at a building's location; analysis of energy saving potentials related to control; novel control algorithms; preparation of a demonstration project in a representative office building.

Zusammenfassung

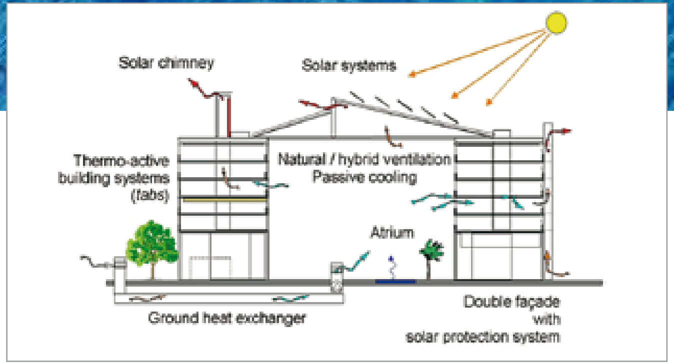
Es wurden vorausschauende Regelstrategien entwickelt mit dem Ziel, den Energieverbrauch von Gebäuden zu vermindern, den Nutzerkomfort zu verbessern, und elektrische Lastspitzen zu begrenzen. Der Fokus lag auf der optimalen Regelung der Jalousien und der Beleuchtung, Heizung, Kühlung und Lüftung in einzelnen Gebäudezonen. Die Resultate waren: Software, Modelle und Datensätze für die simulationsgestützte Evaluation von Regelstrategien; neue Algorithmen für verbesserte Wettervorhersagen am Gebäudestandort; Analyse von Einsparpotentialen im Zusammenhang mit der Regelung; neue Regelalgorithmen; Vorbereitung eines Demonstrationsprojekts.

Résumé

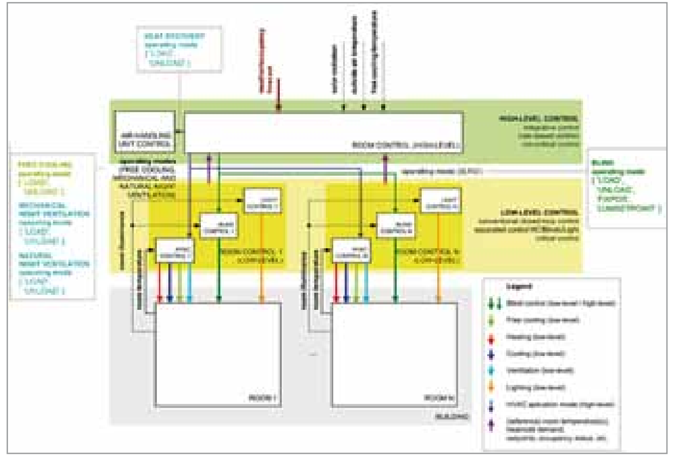
Des stratégies de commandes prévisionelles ont été mises au point pour réduire la consommation d'énergie des bâtiments, améliorer le confort des occupants et limiter les pics de demande électrique. Les résultats atteints était: des logiciels, des modèles et des bases de données pour évaluer des différentes stratégies de réglage par simulation; des nouveaux algorithmes visant à améliorer les prévisions météorologiques sur le lieu d'implantation du bâtiment; l'analyse des potentiels d'économie liés aux réglage; des nouvelles stratégies de réglage; préparation d'un projet de démonstration pour un immeuble de bureaux type.

Statement of the problem

The use of load and weather forecasts for building control is often stated as a promising approach to reduce the energy usage, enhance the occupant comfort and reduce the peak power demand of buildings. However, the approach's feasibility and potential have not been investigated systematically so far. Moreover, there are several reasons why advanced, e.g. predictive, control is likely to become more and more important in order to ensure efficient and correct building operation. Firstly, boundary conditions for the building control task are becoming increasingly dynamic due to the use of intermittent, low carbon energy sources, the high solar gains associated with many modern building designs, and the advent of dynamic electricity prices. Secondly, traditional control approaches are pushed to their limit by new, in terms of control often very demanding building technologies (such as heat pumps, thermally activated building systems, or cooling by night-time ventilation), and by the need to integrate many different building system components.



Example for a modern building system.



Hierarchical scheme for non-standardized control solutions.

Goals

The objectives of the OptiControl project were:

- Development of novel, predictive control strategies in order to reduce energy usage of buildings, enhance occupant comfort, and reduce peak electricity demand;
- Development of software and tools for improved building control;
- Benefit-cost analyses for predictive control;
- Application to a demonstrator building.

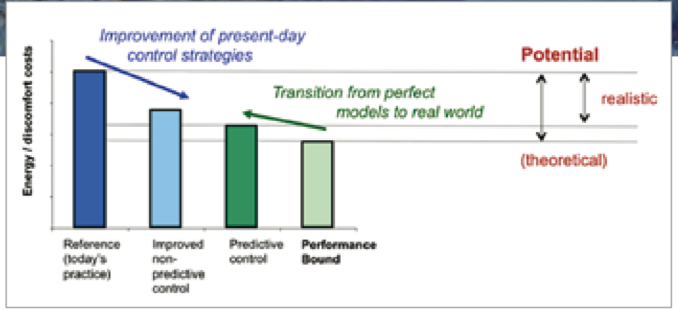
Procedure

The project consisted of three phases: I. Assessment of potential for improved control; II. In-depth analysis of selected cases; and III. Testing of the novel control approaches in a demonstrator building.

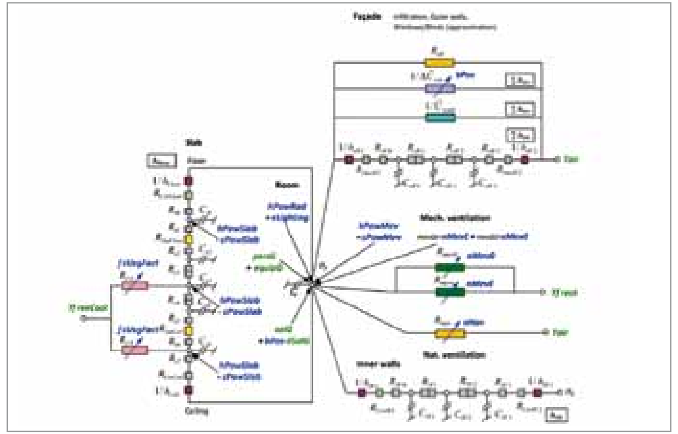
Phase I: Identification of promising candidate applications; selection of a focus application; formal definition of control task; development of methods and software for simulation-based assessment of control strategies; selection of sites, building types and building technical systems to be investigated; development of models, data sets and reference control algorithms; development of algorithms providing the theoretically best possible (perfect predictive) control; large-scale factorial simulation study; assessment of theoretical energy savings potentials given perfect predictive control.

Phase II: Selection of a subset of representative cases with high theoretical potentials; analysis of underlying mechanisms and of peak electricity demand; simulation-based development of practically applicable predictive control algorithms; development of methods for improved local weather forecasts at the building site; robustness and sensitivity studies; development and application of methods for multi-dimensional (energy / comfort / peak electricity demand) assessment of control performance.

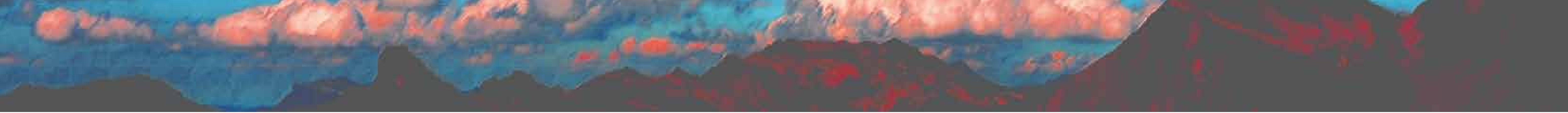
Phase III: Identification of candidate buildings; analysis of their suitability and representativity; selection of target building; initial modeling and assessment of energy savings potential; planning of technical modifications to the building (sensors, actuators, automation system). Setting up of a follow-up project dealing with: further development and validation of simulation models, implementation of technical modifications, iterative adaptation / refinement and performance analysis of control algorithms based on integration of field experiments and simulations, assessment of user acceptance and costs.



Assessment of controller performance.



Thermal model of a building zone.



Results and Outlook

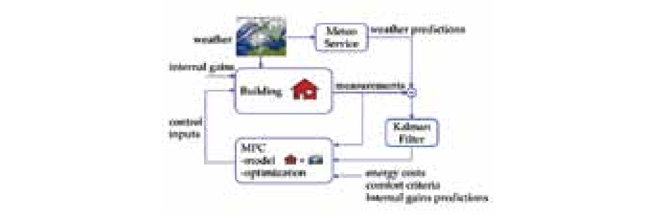
The selected application dealt with the automatic control of blinds, electric lighting, heating, cooling, and ventilation of an individual building zone or room (Integrated Room Automation, IRA). Theoretical energy savings potentials of predictive control as well as practical savings potentials of several low-cost measures related to control were investigated at four representative European sites for 64 building/room types (differing in façade orientation, construction type, building standard etc.), five technical building systems, two different ventilation strategies, and four thermal comfort definitions.

Developed were: (a) improved rule-based, non-predictive, and novel rule-based predictive IRA control algorithms, plus associated tuning rules; (b) a family of entirely new, Model Predictive Control (MPC) algorithms that allow for integration of high-resolution numerical weather forecasts and for the management of peak electricity demand; (c) new algorithms for delivering hourly temperature and radiation forecasts at a building's location at the high quality required by predictive controllers.

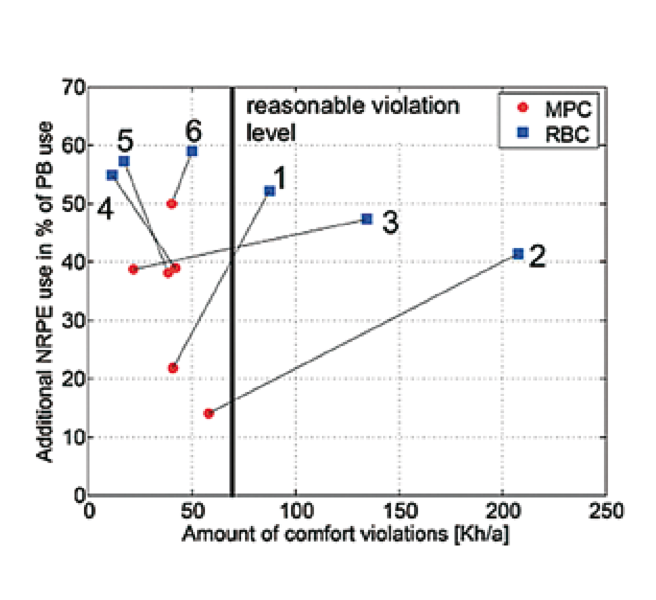
Average theoretical energy savings potentials of predictive control were found to be 16% – 41%. For systems with mechanical ventilation present the introduction of Indoor Air Quality controlled ventilation yielded energy savings by on average 18% – 27%. Improved non-predictive control was found to allow for readily achievable annual energy savings by on average 1% – 15%. Generally, savings potentials were found to vary widely with location, building case, and technical system characteristics.

Detailed analyses for a range of representative building cases demonstrated substantial benefits of the novel MPC algorithms as compared to conventional, non-predictive rule-based control. Advantages were found in terms of energy usage, robustness, tunability, flexibility (e.g., optional limitation of peak power demand, either directly, or in response to time-varying electricity prices), and comfort.

A middle-sized, typical Swiss office building in Allschwil close to Basle, Switzerland, was identified as a suitable demonstrator. Preparations for the demonstration part included negotiations with the building owner, the setting up of a project team, the planning of the needed modifications to the building, and careful initial modelling and simulation work. Based on simulations the theoretical savings potential of predictive control was estimated to be > 20%. The actual demonstration and benefit-cost analysis of the newly developed control solutions will be carried out in a follow-up project.



Application of Model Predictive – to building control.



Comparison of Rule-Based/Model Predictive Control.