Predictive Operation of Sustainable Buildings

The Research Group Sustainable Energy Techniques at the University of Applied Sciences Offenburg is working on the enhancement of the energy efficiency of non residential buildings. The focus is not on architecture or technologies to supply energy, but on building operation by means of building automation systems to control the existing equipment for conversion and distribution of energy.

In recent years more and more new technologies found their way into buildings to supply heating, ventilation and cooling. This includes geothermal energy, solar heating and solar cooling. In the range of energy distribution there are also new possibilities like Thermo-Active Building Systems (TABS), with concrete core conditioning, ceilings with integrated cooling or the use of entire walls for panel heating.

Overheating of buildings is avoided by night ventilation and TABS in conjunction with heat sinks like borehole heat exchangers. Conventional air-conditioning by mechanical cooling systems is avoided because of a bad primary energy balance.

Operating experience shows, that conventional methods of building automation are not sufficient to achieve an energetically optimized building operation. Components are working against each other or are operated in an inappropriate, thus inefficient range of operation. New methods and algorithms have to be developed to use the potential of new technologies in an optimal manner. Integration of modern methods of cybernetics, expert systems or mathematical optimization methods into building automation allows in conjunction with weather forecasts and building simulation a predictive and optimized building operation. The following part of this article describes the development of one of these methods and gives a scope on future works.

In summer 2006 the night ventilation to cool the Solar Info Center SIC in Freiburg, Germany (Fig. 1) was operated with the method of Intelligent Dynamic Building Operation (IDB) which was developed within the framework of the research cluster zafh.net, funded by the Landesstiftung Baden-Württemberg. The Solar Info Center is an office building with a net ground area of about 14.000 m² and a very low primary energy consumption of 45 kWh/m²/a. This is achieved with a reasonable architecture with a window area ratio of 45%, a good thermal insulation and not using a conventional air condition.

Figure 1 – The Solar Info Center SIC in Freiburg, Germany

To avoid summerly overheating of the office areas, the building is flushed with higher air exchange rate at night. Possible potentials of savings are times of cool or changeable weather, in which the fans can be operated with shorter run times and reduced exchange rates. In a first step, one of eight main exhaust ventilators was operated with the new predictive method. Thus the energy consumption of the ventilation and the comfort in the experimental zones could be compared and evaluated with the adjacent building parts.

The Research Group of the Predictive Operation Project: Elmar Bollin, Thomas Feldmann, Jesus da Costa Fernandes

Authoers/Contact:

Research Group NET (Sustainable Energy Techniques), IAF - Institute of Applied Research, Hochschule Offenburg – University of Applied Sciences, Badstr. 24, D-77652 Offenburg, Germany

Prof. Dipl. Ing. Elmar Bollin,
Head of Research Group, Professor on Solar Technology, Building Automation
Phone: +49-781-205-126,
E-mail: bollin@fh-offenburg.de,

Jesus da Costa Fernandes, MSc,
Researcher
Phone: +49-781-205-354,
E-mail: costa@fh-offenburg.de,

Dipl. Ing. Thomas Feldmann,
Researcher
Phone: +49-781-205-342,
E-mail: thomas.feldmann@fh-offenburg.de,

Based on the method of Fuzzy Decision Making, a knowledge-based expert system was developed, which allows the description of human expert knowledge in a mathematical algorithm and makes an automatic analysis possible. The ventilation strategy can be varied individually for every zone, depending on the thermal load or for example in case of vacancies.

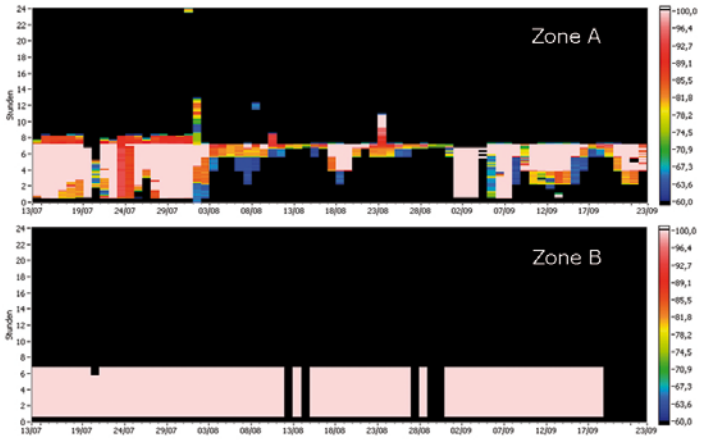

Figure 2 – Ventilator control inputs visualized by carpet plots.

A comparison of the control input of the ventilators is shown with in Fig. 2. The upper plot shows the predictive, the lower the conventional control. The figure shows so-called carpet-plots in which values are presented as different colors. Each vertical bar represents one day beginning with 00:00 at the bottom. The reduced operation times and speeds are clearly visible.

Figure 3 shows the electric power consumption of the two control strategies. The predictive control with the expert system saved 38% of electrical energy compared to the conventional control. Detailed studies showed that the reduced night ventilation did not lead to a reduction of comfort.

After this successful long term experiment, the predictive control strategy was implemented directly to the controllers of the building automation (DDC) and extended to all main exhaust ventilators in the whole building.

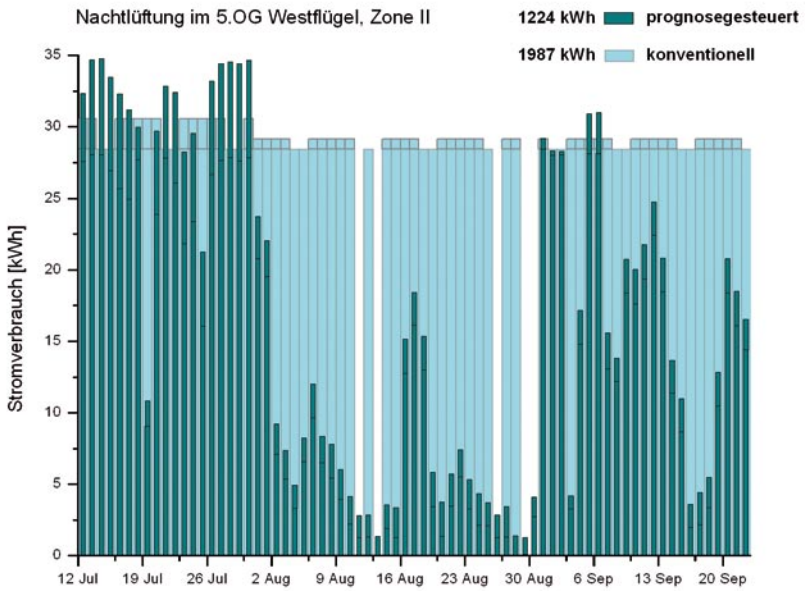

Figure 3 – Comparison of electrical power consumption

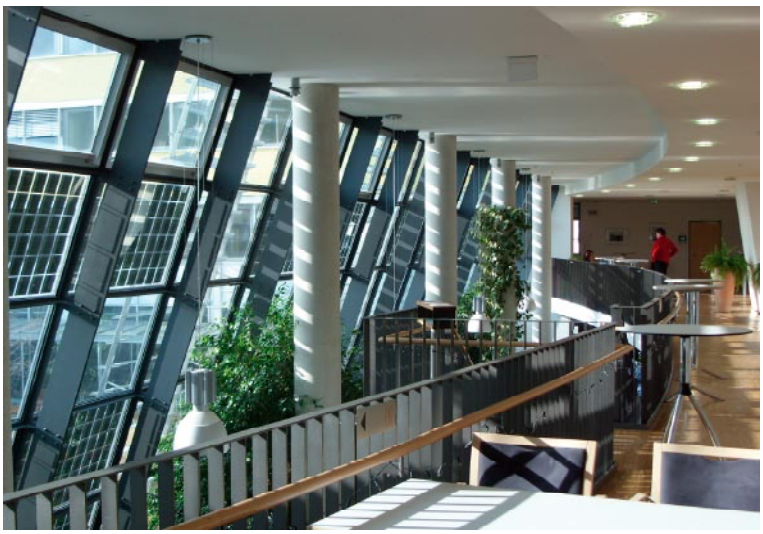

Figure 4: View to the facade with window integrated PV mudules at the lounge of the solar info center sic Freiburg

For the reception of the weather forecast a web service was established in cooperation with a weather service provider. This makes the elegant integration of forecasts into the building automation possible. There are works on a further method for future projects, which allows the reception via long wave broadcast. Microchips, similar to those used in radio-controlled watches, will be able to receive extensive forecasts. Internet connections with all their risks of abuse will then no longer be needed.

The research project „Simulation-Supported Automation for Sustainable Air-Conditioning of Buildings in Summer", a project of the research programme "Klimazwei", funded by the Federal Ministry of Education and Research, works on an application, which aims at the optimization of a concrete core conditioning system. A concrete ceiling has a very high inertia and needs several hours to change temperature by using the water pipes in the core for heating or cooling. Conventional building automation systems meet considerable problems when controlling such processes. A Model Predictive Control (MPC) with an integrated model of the building and the use of weather forecasts can improve the performance significantly. The controller knows in advance how the building will behave in the next future (2-3 days). Thus it is possible to act early enough to achieve a preconditioning of the building.

Objective of the new algorithms must always be, to look at different trades of the building and the automation as an integral overall system to avoid ineffective operating conditions.