

IOB - SIMULATION AND AUTOMATION ASSISTED INFORMATION AND CONTROL TOOL FOR SUSTAINABLE BUILDING OPERATION

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ABSTRACT

Sustainability aspects on building operation force a building manager to continuous observation of actual states concerning building use, energy and media flows. In the presented approach a communication structure was built up to use different software applications and tools in order to optimize the operation of a building.

Using simulation tools the supply situation and the environmental conditions of a building are analyzed. Based on actual state, historical data, demand prediction, weather forecasts and use schedules decisions are taken to launch actions that lead to operation conditions like the minimized use of fossil fuels.

A SCADA-type historical database coupled with visualization, evaluation and control functions the TCP/IP-based networking was tested for its ability to integrate software tools and different environments. At different places in Baden-Württemberg optimization is done for the operation of a seminar room with its equipment for ventilation with pre-heating by different renewable energy sources.

KEYWORDS

energy management, sustainable buildings, remote control via Internet

INTRODUCTION

The zafh.net (Zentrum für angewandte Forschung an Fachhochschulen - Nachhaltige Energietechnik) is a project started in 2003 with the intention to establish a centre of competence and expertise on building energy research in Baden-Württemberg (Germany). The University of Applied Sciences Offenburg (UAS Offenburg) is one of five project partners and responsible for new energy management concepts and methods for a sustainable building energy supply.

The development of a sustainable building operation tool requires several other tools to operate a building to meet different criteria like sustainability, comfort or cost reduction. Many of the software tools are applied in the planning phase of a building but rarely or not used as assisting tools for building operation. Former scientific works [1] revealed the importance of control in building management systems and the role of simulation.

According to the focus on sustainable energy technologies the zafh.net research network is interested in a strong integration of renewable energy sources for the building energy supply leading to minimized emissions of carbon dioxide but assuring required comfort conditions. To achieve the goals and to be able to perform cooperational energy research activities with distributed universities a new networking infrastructure was necessary.

The partner universities are operating with different development environments and software tools. As a consequence the networking must be done with an interface structure allowing

communication between the universities without interference and disturbing effects caused for example by firewall configurations. A chosen demonstrational object/building must be accessible via Internet and easily be integrated to the network.

METHODS "

A crucial aspect for a good performance in a research network is a good data communication structure. The evidence of a common level for networking is obvious. Respecting the distributed competences of the partners the TCP/IP-networking via Internet favourizes conceptionally the remote management and operation of buildings. Ressources are used on demand wherever they are located. They serve to realize an optimum for the sustainable operation of a building with its technical equipment and energy supply.

The research group of the UAS Offenburg worked out a solution using for example simulation results from Stuttgart and weather forecasts, use and load profiles from Reutlingen. With the intelligent dynamic building operation (IDB) tool the input is processed in Offenburg to optimize the energy supply and climate of a seminar room at the UAS Biberach. Parallely newly designed controllers are tested by the UAS Reutlingen and the simulation assisted monitoring of specific energy sources or a heat exchanger is done by the UAS Stuttgart.

Conventional building automation (PLC, DDC) must ensure an autonomous operation corresponding to the State-of-Art if there were a breakdown of the overlaid control or the internet communication link were interrupted. Figure 1 shows the extension of the building automation by adding overlaid functions which cannot be covered by the building automation itself, because the functions are too complex, the information needed is not available or the overview is missing or even the abilities of the building automation are limited.

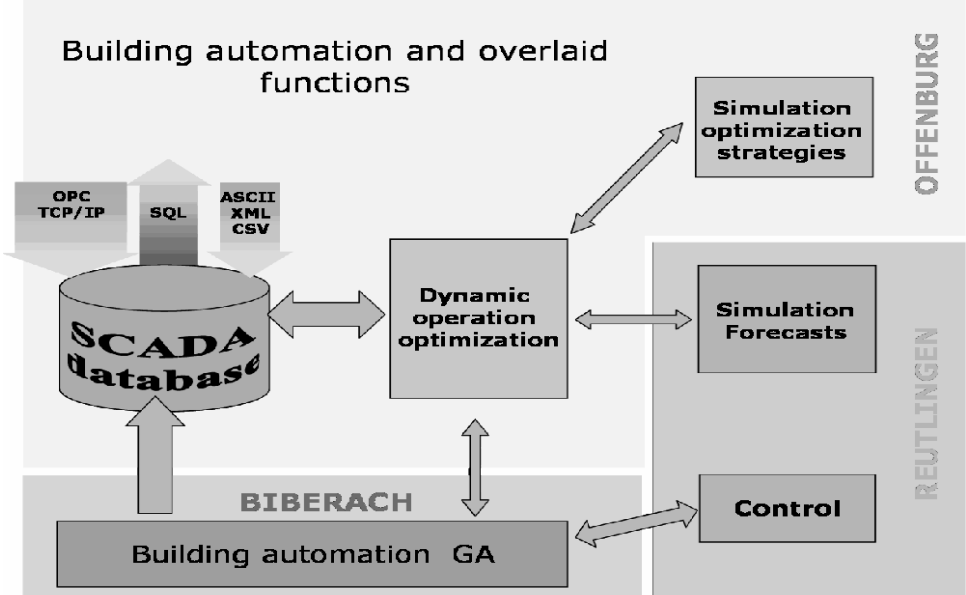


Figure 1: Networking for the **I**ntelligent **D**ynamic **B**uilding operation (IDB)

A SCADA-type database is the core element of the IDB. Data can be fed to the database directly via OPC-Server or TCP/IP-Communication or even with datafiles of common formats like ASCII, CSV or XML. With SQL-calls and other call functions requested data can be read out for processing, decision making and visualization.

The dynamic operation optimization block as the decision making element uses an optimization software to process available information and simulation results. The output is

the generation of actions for the building automation or the communication with a simulation agent to start supporting simulations, request specific COP's or forecasts. The functional components of the IDB can be specified as the following:

- Analysis of the buildings' behaviour with actual and historical data
- Evaluation using simulation, forecasts and demand profiles
- Decision making for optimization purposes
- Launch of actions to achieve the new setpoint profile or meet the requested operation criteria

RESULTS

Going to details the specified functional components for the IDB led to the described programming packages oriented on the seminar room with its complex ventilation unit as demonstrational object. The programming of the IDB was done in the graphical language G of the LabVIEW-environment [2]. The LabVIEW-programs are able to call simulation tools and optimization tools and to communicate over all known interfaces of the zafh.net research network. The graphical user interface to handle the processes and manage the IDB-activities is built up with control and communication panels, visualization windows, pop-up menus, scroll-bars and folders. Many aspects are leaned on the mostly familiar MS Windows-Appearance. Others are held closer to surfaces of building automation and monitoring tools with elements for input, control and visualization.

Visualization - historical data and actual data

For the historical database Citadel5 [3] was chosen because of advantages in the LabVIEW-environment. The measured data are stored event or hysteresis oriented for more economic use of memory. The database is fed with online-datastreams as well as with ASCII-files or XML-data. With the compatibility for SQL there is an access to various software tools possible. In Figure 2 the air temperature at a cross flow heat exchanger is shown, monitored with continuously refreshed actual data and historic trend.

For easier analysis and navigation zoom- and pan-functions and selectable cursors are available as well as definable time slides. In the right part of the window of figure 2 the available variables/datapoints are listed. Any choice can be done out of this list.

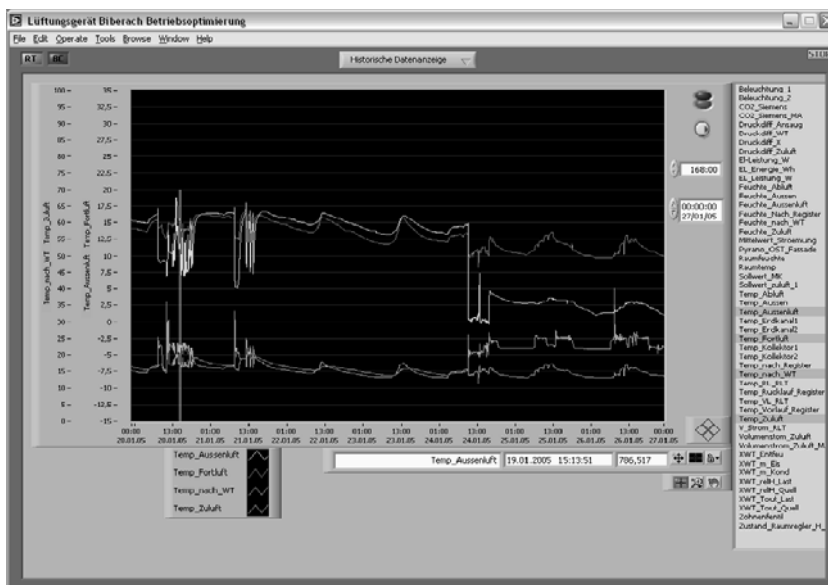


Figure 2: Visualization of historical and actual data

Analysis of characteristic curves

A good tool to visualize a large amount of data in one sight is the use of intensity or carpet plots [4]. As an example figure 3 shows an overview on data slides of 200 days, each day with an accuracy of 5 minute-values. The example data are historical data of a PV-hybrid-system in Offenburg showing in the upper window the times of operation for the backup-generator (clear spots) and in the lower window the voltage level of the PV-generator. There is a separation easily possible between the charging, puls width modulated operation or not charging (black areas) of the battery. The carpet plot facilitates the analysis work of large amounts of data and is applicable for the seminar room in Biberach.

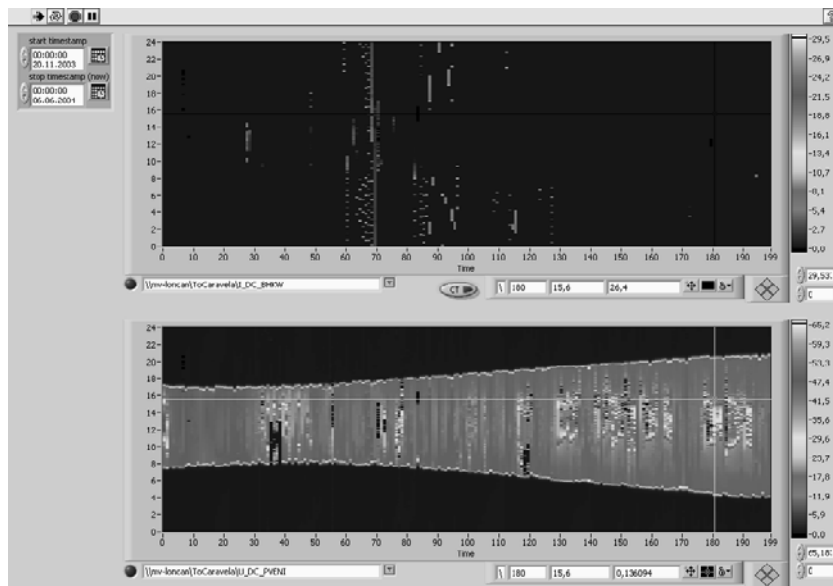


Figure 3: Intensity or Carpet plots for analysis

Visualization - flow charts and overview diagrams

Another type of visualization are flow charts and overview diagrams of heat flows, energy balances, carbon dioxide emissions or savings. To demonstrate the importance of renewable energy sources in a sustainable building operation and for a fast overview about the energy flows and the directly coupled carbon dioxide emissions or savings, a flow chart window was programmed. The actual energy demand for the seminar room and the contributions of the different energy sources are visualized. Actually the renewable energy sources are represented as an energy-mix of pure ambient air, sucked over a geothermal heat exchanger and/or a solar air collector. Supporting energy contributions come from the heat recovery and if necessary from the heat pump or the central heating of the building.

Simulation and decision making

The optimized start/stop-function for the room heating is an easy example of a dynamic optimization schematically shown in figure 4. The setpoint for the desired room temperature should be achieved the latest as possible. On the other hand the setpoint for switch-off of the heating should be set the earliest as possible if times with need of heating were predicted in the use schedule.

For this tasks the thermal behaviour of the room can be simulated with the simulation tool TRNSYS [5] using the weather history, a forecast and the use schedule for the room. The output is a predicted load profile, the foreseen energy demand and the contents for humidity and carbon dioxide. With the variation of start-/stop-setpoints the simulation results are

analysed and evaluated. This can be done with optimization algorithms in LabVIEW or with optimization tools like GenOpt [6].

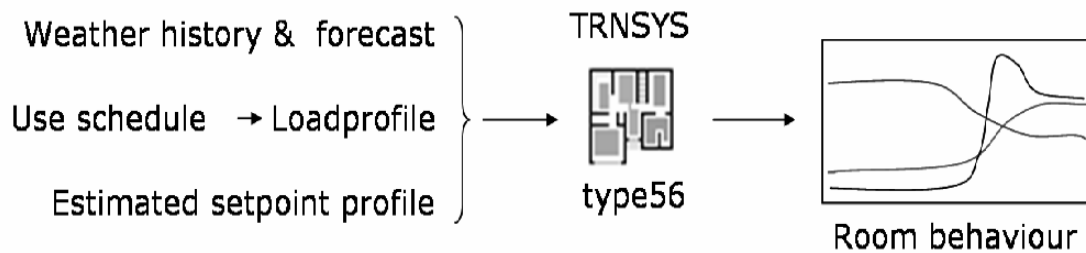


Figure 4: Structure for a simulation assisted Start/stop-function for a room heating

Ongoing works are handling the optimization of night ventilation in the summer period and the operation optimization of available renewable energy sources. Here a new concept with Fuzzy Decision Making was developed by the UAS Reutlingen to control the flaps of the air ducts for the ventilation unit. Other tools developed in Reutlingen are a simulation agent and a forecast tool. Both tools were developed in Matlab/Simulink[7] and are communicating with the IDB in Offenburg over a DataSocket-interface [8]. The communication with the building automation in Biberach is done with Labmap [9]. Both DataSocket and Labmap are TCP/IP-protocols with an Application Programming Interface (API) to communicate with different software.

Simulation assisted monitoring

As one of the first successful experiments to test the simulation assisted operation a grid connected PV generator at the UAS Offenburg was simulated with INSEL[10]. The measured solar irradiation and temperatures were sent as input values to the INSEL simulation in Stuttgart. The output of the simulation was sent back to Offenburg and there compared with the online values for voltage and current.

Further tests on simulation assisted monitoring and control are ongoing for a cross flow heat exchanger and a solar air collector.

DISCUSSION

The major part of the development works on the IDB are completed and partly tested on available data and online-datastreams. The realization of the software tool in the LabVIEW-environment was proved as good choice with excellent extension possibilities for the operation of entire buildings. Some features had to be tested on available systems at the UAS Offenburg others were successfully tested on the chosen demonstration object in Biberach. The current state of IDB tool already demonstrates the abilities of a simulation and automation assisted operation for a complex ventilation system for a seminar room. In the two years of research work not all functions were completely realized and some are not operating sufficiently. The main work packages left are concentrated on the use of optimization tools like GenOpt, validation of existing and developed models of the room, the energy sources and the components and the improvement of process for the decision making. Finally the validation of the IDB operation on the seminar room in Biberach is left but planned for this year. The works on the model based simulation assisted monitoring and control of the complete assembly (seminar room with complex ventilation) are ongoing.

ACKNOWLEDGEMENTS

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