Development of the HVAC Control System by the Concurrent Simulation

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ABSTRACT

The idea proposed in this paper is to control the HVAC equipment with predicting the heating/cooling loads and indoor conditions by computational simulation according to the target, such as energy consumption, energy cost, \(\text{CO}_2\) generation and indoor thermal comfort. The simulation inputs is given by the measurement results, e.g. weather conditions, indoor temperature and humidity on the spot. The developed system controls HVAC system by using the real-time simulation, and investigates the performance of this system. The link and the data flow of the control cycle of the measurement, simulation and HVAC control were examined and demonstrated in the experiment. The result of the experiment for the cycle of the measurement, simulation and HVAC control is described. The experiment and simulation based on the prototype installed at the research facilities and on the virtual system for NIES building are shown as some examples. The former is a climate chamber as a typical and real size office including the heat source of the building. Simulation is carried out by TRNSYS and GAMS using the measured data and it shows the modified control method of HVAC system considering the results of TRNSYS simulation.

KEYWORDS

HVAC control, Simulation, Measurement, BAC-net

INTRODUCTION

In Japan, \(\text{CO}_2\) emission rate from the field of the public welfare is 15.5 %, and a rate of increase from 1990 to 2001 is 30.9 %. Especially, the energy consumption in buildings is one third of the total energy in Japan. Therefore, it is important to reconsider the energy use for the air conditioning that holds a most part of the total energy in buildings. One of the most effective methods to reduce energy consumption in buildings is to control properly the HVAC equipment that is variable by influence of thermal property of the building envelope, occupants’ schedule and heat generation from the OA apparatus.

METHODS

The Components of the Developed Control System
The control system configuration of the HVAC equipment is shown in Figure 1 and consists of three components;
1) The data acquisition system of the conventional control system,
2) The control of the HVAC and heat source of the conventional control system,
3) The simulation system of heat load calculation TRNSYS and mathematical planning tool GAMS.

Figure 1: Automatic control system of HVAC equipments

Data communication on BAC-net

DATA ACQUISITION

<table>
<thead>
<tr>
<th>Icon: Intelligent controller</th>
<th>Icon: Intelligent controller</th>
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<tr>
<td>RS</td>
<td>sensor</td>
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<td>RS</td>
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RS : remote communication device (DDC : Direct Digital Controller)

Figure 2: Automatic control system on the BAC-net
The components function with data communication on the BAC-net indicated in Figure 2, predicting the heating/cooling loads and indoor conditions by computational simulation. The simulation has the target of energy consumption, energy cost, CO₂ generation and indoor thermal comfort.

**The Functional Procedure of the Control System**

It provides several scenarios that allow the HVAC operation schedule to achieve each target before the control starting. The operator will choose one of the scenarios where they may conflict, and the resulted schedule is applied for next operating period, e.g. 24hours.

The data based on the chosen scenario is transferred to the tool GAMS that optimizes the control command to HVAC equipments. It applies the mathematical planning model and executes iterative calculation to solve the whole set of equations.

The simulation inputs is given by the measurement results (lower left in Figure 1), i.e. weather conditions, indoor temperature and humidity on the spot, etc. Therefore the developed system controls HVAC system by using the concurrent simulation, and investigates the performance of this system afterward.

The control system is running in an experimental room installed VAV system, including heat source of related rooms, in research facilities and makes HVAC operation with concurrent simulation coexisting with conventional HVAC control system. Also the other one runs on PC that has the virtual model of the sensors and DDC control equipments in NIES building, and a set of necessary data.

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**Figure 3:** Simplified and detailed zoning plans of the NIES building
EXAMPLES OF THE COMPONENT PERFORMANCE

Simulation Using NIES building by TRNSYS

A building of NIES, National Institute of Environmental Studies, is simulated by TRNSYS and the two model are shown in Figure 3 where rooms are gathered as one thermal zone surrounded by bold lines.

Some results are indicated on Figure 4. Simplified model and detailed model provides small difference and the former is slightly less. And the control equipment for the environmental effects could reduce the cooling load considerably.

Optimized HVAC Control Calculated by GAMS

The result of TRNSYS simulation is transferred to GAMS, actually the data from TRNSYS is sent to NAS, Network Application Server, and GAMS acquires necessary data from NAS. The energy and data flow are shown in Figure 5.

A calculated example of one day is shown in Table 1. The measurement data of 2005 September 26 is compared to the estimated values of the optimized control. The schedule of HVAC equipments is assumed to improve the performance, and GAMS provides the energy costs, etc.

DISCUSSION

The system to provide the optimized HVAC control to achieve the given target is shown as the system consisting of the cycle of the measurement, simulation and HVAC control. The concurrent simulation is carried out by TRNSYS using the measured data and the command to DDC is calculated by optimization tool GAMS. To provide the open system it works on the PC for the simulation and data storage on the internet, i.e. BAC-net.

![Diagram showing the result of annual heating and cooling loads](image)
The components of simulation and HVAC control indicate the capabilities. For example, the simulation calculates heat load, e.g. the time step of 10 minutes, in annual period, and GAMS makes the optimized HVAC control command for each time step. If the scenario of HVAC control according to the target is selected by the operator, the system starts to operate HVAC automatically.

**SUMMARY**

The outline of the auto-control system of building equipments and its developing project has been introduced. The control system is explained in terms of the modeling and calculation of targeted building, the structure and data flow of the system where the data are stored in the data server and the communication is done via the internet, i.e. BAC-net.

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**Figure 5:** Data and energy flow for heat source optimized operation in NIES building
Table 1: Comparison between measurement and simulation results

<table>
<thead>
<tr>
<th></th>
<th>Operation cost kJPY/day</th>
<th>CO2 generation Ton/day</th>
<th>Energy consumption GJ/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation of optimized control</td>
<td>38.24</td>
<td>1.346</td>
<td>32.58</td>
</tr>
<tr>
<td>Actual operation</td>
<td>41.52</td>
<td>1.465</td>
<td>35.35</td>
</tr>
</tbody>
</table>

The capabilities of the components of the control system are shown; the building energy simulation provides the estimation of the energy conservation and mathematical planning makes the HVAC control commands based on the simulation result. A real system is installed in research facilities is operating HVAC system and has been operated. A virtual system of NIES is running on PC and will be installed this year.

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**References**

