BEMS and HVAC Control System Utilizing Simulation and the Data Platform on the Internet

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ABSTRACT
This paper describes the optimum HVAC control system that the simulation is executed using the data of BEMS and the weather forecasting, etc. The thermal characteristics such as heat load are calculated by the simulation code TRNSYS with modeling the targeted building, and many scenarios for the next day are indicated in terms of energy consumption, CO_2 generation rate, thermal comfort and cost. After the operator has chosen a scenario, the optimized operation schedule of the heat source is provided by the simulation code GAMS. All the data are treated on the data platform, BAC-Flex, that stores and exchanges them on the internet, and the platform can work with existing LAN communication system. This system can be adjusted concerning to the building model, the equipment operation, the set temperature, etc. in daily basis. The brief structure of the system is explained and an example applied to the school is introduced.

1. INTRODUCTION

It is necessary for Japanese public welfare section to reduce CO_2 emission rate. The emission from the field of the public welfare in Japan is 15.5 %, and a rate of increase from 1990 to 2001 is 30.9 %. The energy consumption in buildings is one third of the total energy in Japan, so that 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 install the advanced HVAC equipments and to control them properly, that is variable by influence of thermal property of the building envelope, occupants' schedule and heat generation from the OA apparatus.

To achieve the target, the role of simulation is very important and it may be pursued by the embedded system including of BEMS, simulation and related control systems, as mentioned in the future of the building simulation (Malkawi, 2004). This paper describes the platform on the internet that enables the combined system as the above based on the project to develop the system (Utsumi, 2006).

2. THE PROTPTYPE OF THE DEVELOPED SYSTEM

2.1 The Brief Structure 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, e.g. BEMS
2) The control of the HVAC and heat source of the conventional control system, e.g. DDC
3) The simulation system of heat load calculation TRNSYS and mathematical planning tool GAMS. The former calculates

necessary heat load according to the building thermal property, weather forecasting, etc. and the latter provides the optimal heat source operating schedule considering the number and performance, etc. of the equipments.

The components function with data

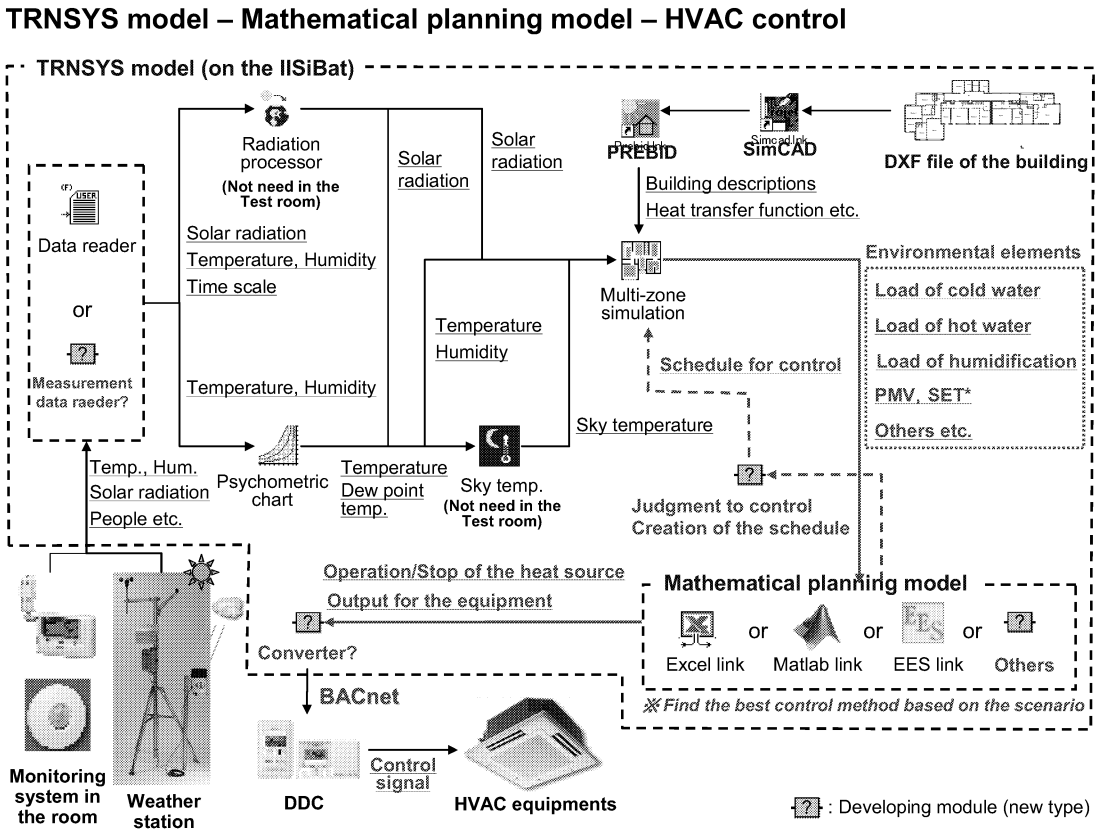


Figure 1: The structure of the automatic control system of HVAC equipments

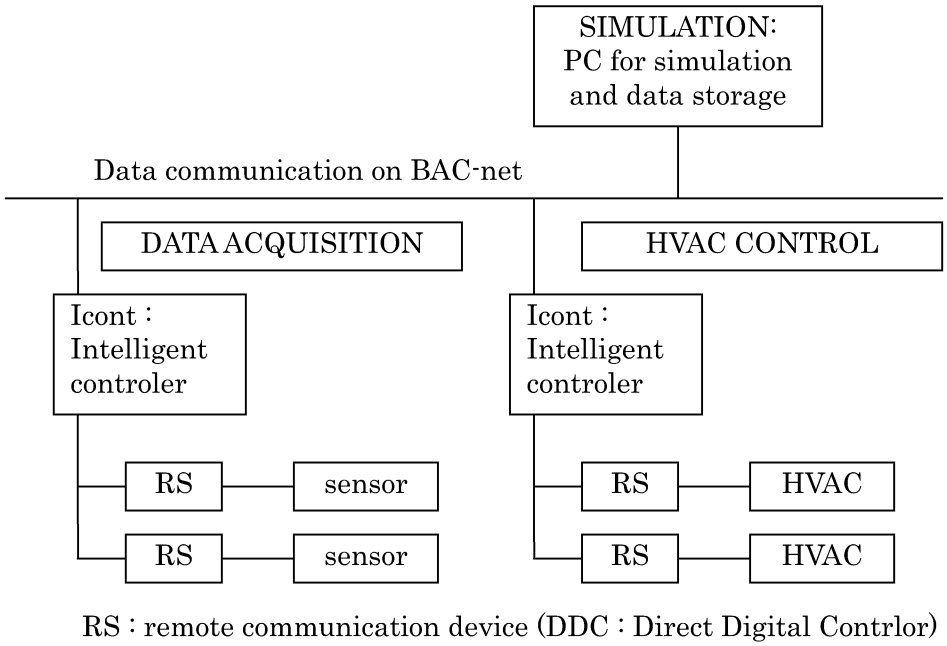


Figure 2: Automatic control system on the BAC-net

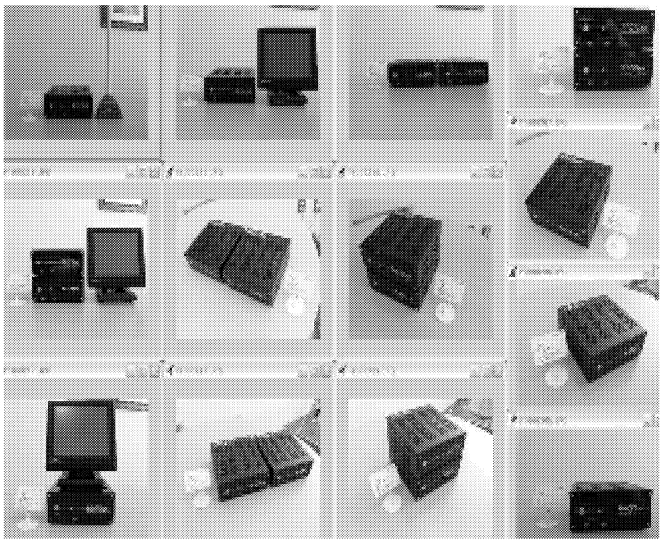


Figure 3: The prototype of BAC-Flex applied to office buildings

by computational simulation. The 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, CO_2 generation and thermal comfort.

Several BAC-Flex are shown in Figure 3 and they can be in the shape of box that is the size of palm and can be installed in USB memory that evolves in the installed PC.

2.2 The Function and Procedure of the Control System

The procedure and the data flow of BAC-Flex as a prototype are shown in Figure 4. After executing the simulation to provide heat load, the system provides several scenarios that allow the HVAC

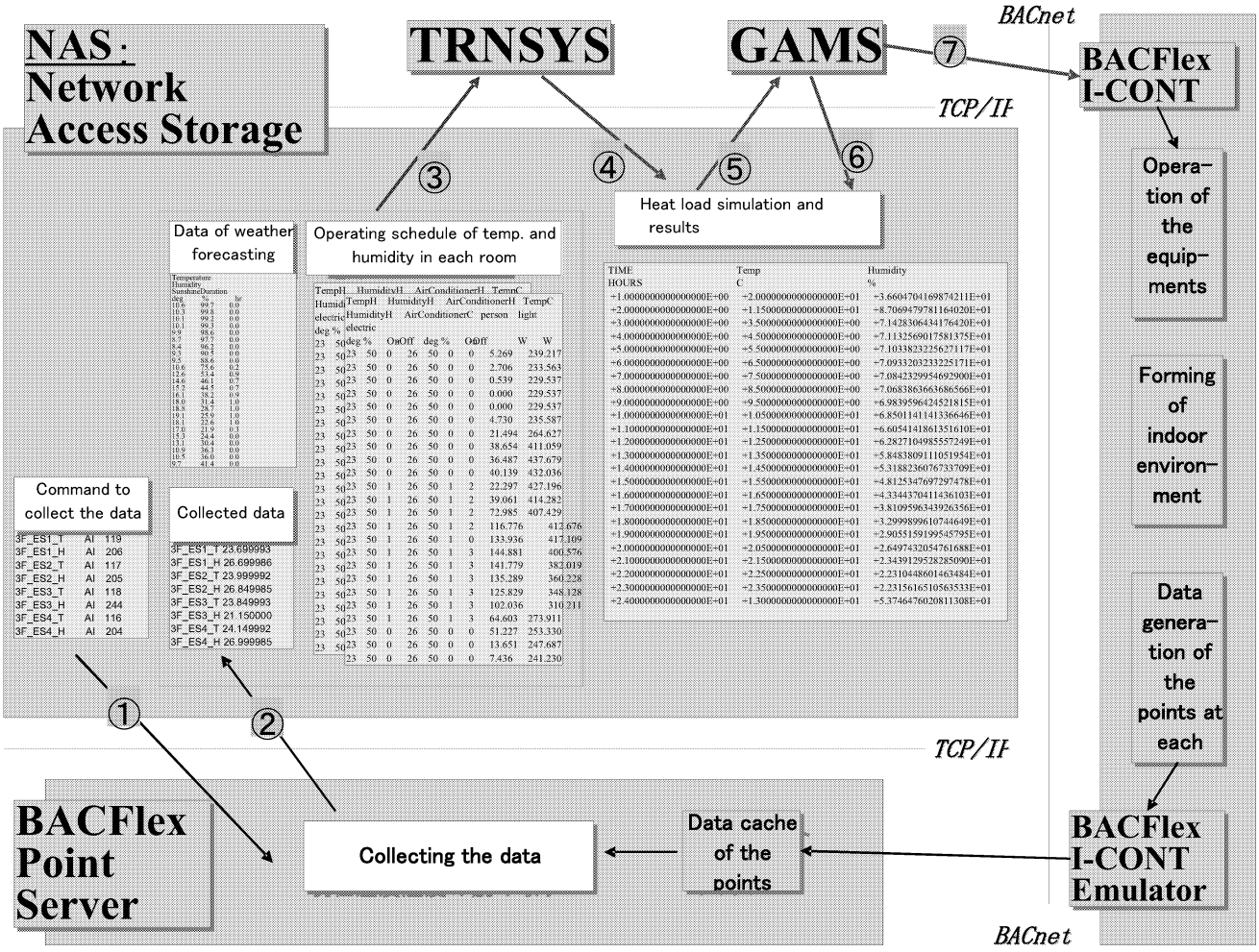


Figure 4: The procedure and the data flow of BAC-Flex

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 input by the simulation is given by the measurement results (lower left in Figure 4), 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 can run on PC that has the virtual model of the sensors and DDC control equipments with a set of necessary data. Also it can be operated with existing LAN protocol simultaneously, that is, it may constitute the MBCN (Multiplex BEMS Computing Networks) across the various networks.

3. THE INSTALLATION OF THE SCHOOL BUILDING

3.1 The Brief Structure of the Developed Control System

The system is installed at CTC, Collaboration of Technology Center, of Miyagi National College of Technology, 38.north latitude and 140.east longitude. It is 410m^2 of floor area and has 4 rooms at 1st floor and 3 rooms at 2nd floor where the building has 4 floors. There are three outdoor heat sources and are linked to the distributed heating and cooling systems (Figure 5(a)(b)).

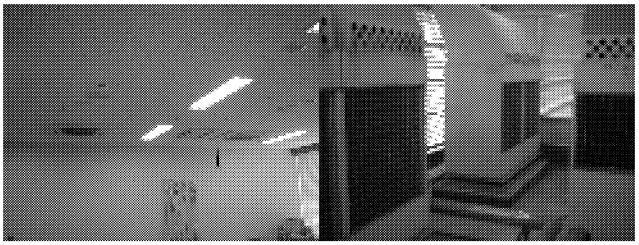
3.2 The View of the Installed System

The view and an example of the configuration of the control system installed are shown in Figure 5 and 6. The control system (Figure 5(c)) can be located in a room that has the internet connection. The BEMS data is acquired by the BAC-net protocol (Figure 5(d), (e)). The sensor of temperature and humidity is set at the center of the room (Figure 5(f)) because it can reflect the situation in the room adding to the original sensors of the distributed heating and cooling system.

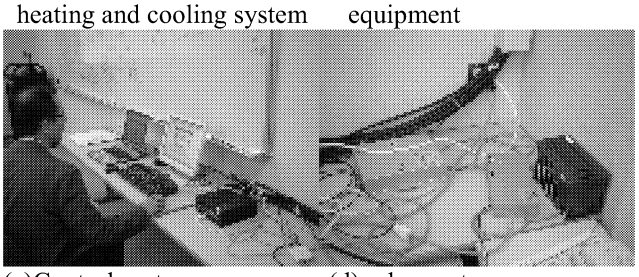
In case that the equipment does not have BAC-net protocol, the relay system for each equipment at the room is customized (Figure 5 (d)). Generally the weather monitoring system may be set to have the data, particularly the solar radiation rate. Some construction works were necessary for the cable connections in this case.

Figure 6 indicates the actual data connection. As the ventilation systems with heat exchanger in rooms do not correspond to the BAC-net, the relay system transfers the data according to the conventional communication ports, e.g. ON/OFF, the operational mode, etc. The watt-hour meters to monitor the power consumption are treated in same manner.

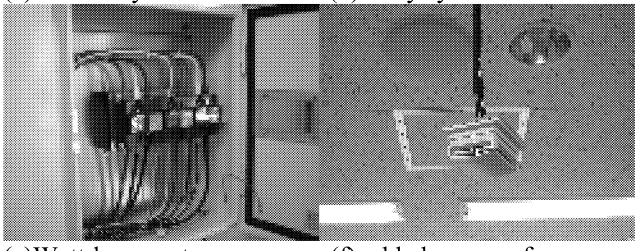
There are three outdoor heat sources are located right bottom in the figure. The above box, GB-50, that has its own protocol, acquire data and can control the distributed heating and cooling system.



(a)The ceiling with distributed heating and cooling system (b)outdoor heat source equipment



(c)Control system (d) relay system



(e)Watt-hour meter (f) added sensor of temperature and humidity

Figure 5: The view of the installed BAC-Flex at school

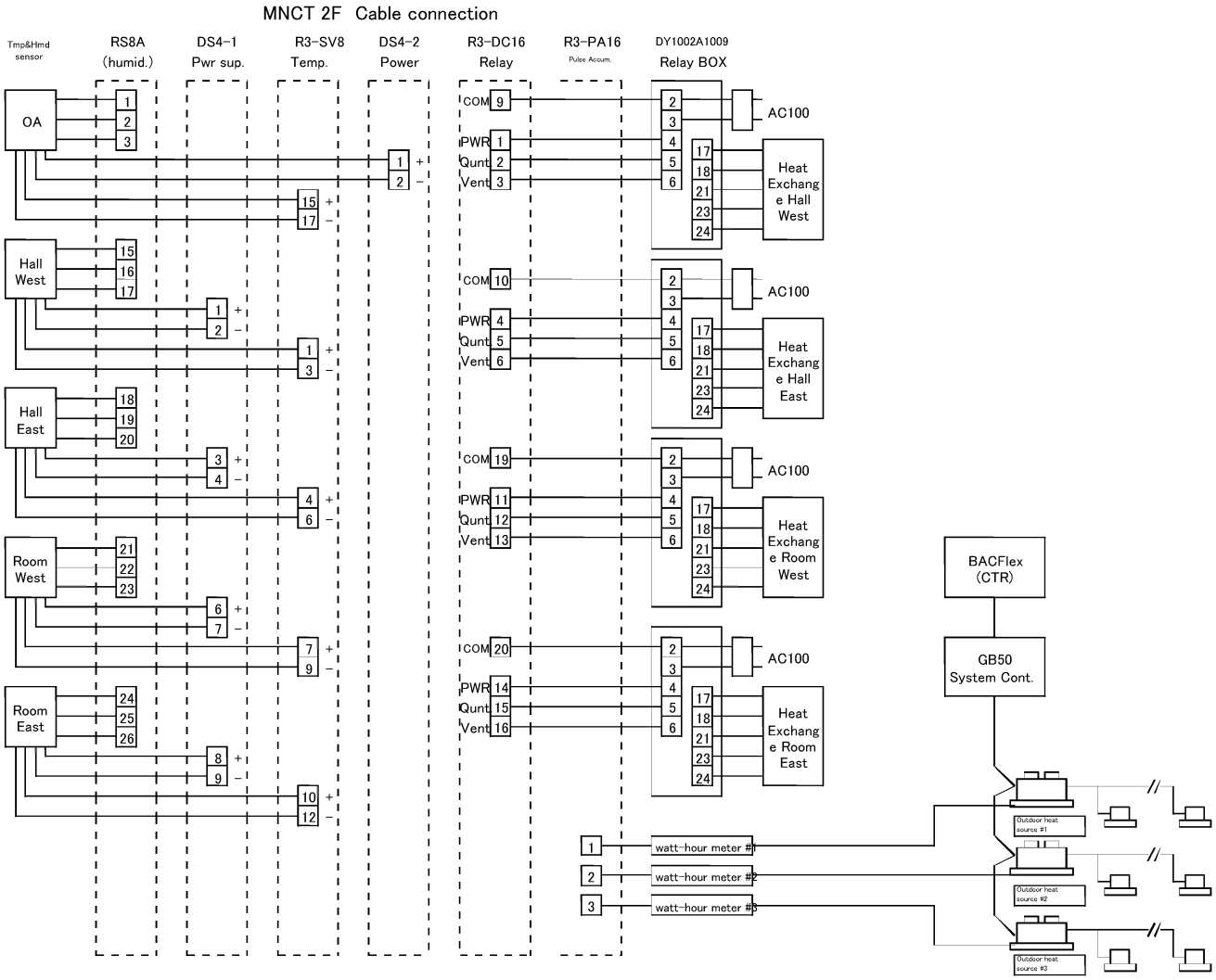


Figure 6: An example of cable connection designed for BAC-net

It also deals with the input and output of the data in the format of BAC-net and is connected to BAC-Flex.

4. DISCUSSIONS

4.1 The Feasibility of the System in Practical Field

The technologies concerning to the system are relatively matured and the organizing them to achieve the target with feasible resources is essential.

Though the developed system can utilize the existing BEMS that provides the data in buildings, e.g. room temperature, power consumption, etc., it needs more data and instruments.

For example, the weather data in situ is necessary to adjust the building simulation model in terms of thermal behavior at early stage and to check the difference of the monitored data, e.g. energy consumption, in operational stage.

Not all the building equipments support BAC-net protocol at this moment and the small size of buildings may not have BEMS or monitoring system. Then the tailored relay system must be built and the construction work for network cables, etc. with the targeted building occurs.

This paper describes the full set of the system and it is applicable for the building that has BEMS. But the simplified system for the limited target can be

suitable for small building. For instance, it applies the reduced number of measuring points and uses the weather data of the closest weather station, etc.

The accumulation of expertise of the construction, tuning, operation in many usages of buildings may offer the simplified systems at some levels, that is, CO_2 generation, energy consumption, comfort and cost. Also the typical operation schedules according to the climate may be available.

4.2 The Performance of the System

As often pointed out, the replacement of less efficient system and the stopping the use of the unnecessary equipments can provide considerable energy reduction. This system can predict the effect with the model of actual building and the climate on site, therefore, the performance of applied system can be estimated correctly. For example, the experiment with the prototype reveals the reduction of over 50% (Utsumi 2006).

At the operation stage the difference between the monitored data and the prediction can be adjusted with modifying the building simulation model and optimum operation calculation every 24 hours in this case.

Though the amount of calculation is large depending on the size and number of buildings and heat sources, PC performance embedded in BAC-Flex in terms of computing TRNSYS and GAMS for the building of 410m^2 is enough for the control and the size is small enough to put in a room with the internet access.

This capability allows the system to be installed into the building more than 10,000m^2 floor area. Also the system applies LINUX and BAC-net that are open, therefore, it is possible to construct the control system that exists over more broad area, such as the urban district.

It will need the protocol to clustering and controlling in the district, the libraries according to the building types and the usages of the system, and the simulator of the district energy consumption behavior, etc.

5. CONCLUSIONS

The brief structure of the control system utilizing simulation and the platform on the internet are described. It proceeds from measurement including BEMS data, simulation of the prediction of the heat load and the optimization of heat source, equipment control via internet and so on.

After indicating the components and their functions, the feasibility and the performance in terms of practical works are discussed. It is pointed out that expanding the system to the broader area, e.g. clustering the data and control over urban district, is possible, because the system applies Linux and BAC-net protocol and it works on the internet.

Subsequent experiment for annul period with the installed system at school is being executed.

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