REAL-TIMES CONTROL OF HVAC USING BEMS AT ENERGY OPERATING CENTER

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ABSTRACT

The widespread growth of BEMS (building energy management system) increases in the developed countries such as U.S., Europe, Korea, Japan, and so on, as interest of saving building energy consumption rises. A BEMS facilitates the integration and interoperation of equipment, appliance and devices via a network of sensors and controls. It offers remote management of energy-and resource intensive building subsystems, such as HVAC (Heating, Ventilating and Air-Conditioning) and lighting, from a central platform, web-based portal, or cloud-based software application. In this paper, we suggest that a method of saving building energy consumption is applied to target buildings from a remote operating center using control function of HVAC system in BEMS and a control server at the operating center. So we set a building for applying energy-saving methods. This building is one of buildings in Sejong special self-govering city, Korea. The BEMS has been installed in the selected buildings and is coupled with the EOC (energy operating center). We could get the environment information such as indoors and outdoors temperature, electricity usage, and setting temperature of HVAC system at the selected building, because all environment data measured from BEMS are collected in this center. At this center, a decision making process on operating HVAC system is implemented using a simulation server and gathered environment data. Results of hourly schedule saving energy consumption are obtained and stored. These results were applied to the target building using control function of HVAC system in BEMS and a control server at the operation center. As applying this method, we will result in energy saving more than a previous BEMS

Keywords: Building Energy Information Modeling (BEIM), Building energy simulation, Building Energy Monitoring System (BEMS), Energy Operating Center (EOC), Genetic Algorithms (GA)

1. INTRODUCTION

Energy efficiency and climate change are topical issues the world over. The building sector plays an important role as it accounts for significant percentages of national energy consumption: 23% for Spain, 25% for Japan, 28% for China, 37% for EU, 39% for the UK, 42% for Brazil, over 47% for Botswana, 47% for Switzerland, etc. It is for this reason that a lot of effort is made to reduce energy consumption in buildings. (Masoso and Grobler 2010)

Energy conservation in the building sector is now attracting a great deal more attention throughout the world with regard to environmental preservation of the Earth. In recent years, numerous high energy efficiency equipment devices, such as cogeneration systems, triple-effect absorption refrigerators, and high-efficiency air-source heat pump, etc, have been developed. However, the use of such high energy efficiency equipment does not necessarily in itself achieve the optimum energy saving. This is because energy consumption is highly dependent on the combination and operation of equipment used. Thus, the best combination and operation conditions must be planned to achieve the maximum energy saving. (Ooka and Komamura 2009)

From this perspective, Smart Grid has important functions to find combination and operation condition of equipment used. For reference, Smart Grid refers to a system that comprises intelligent electricity sensors, automated metering, and specialized computer systems to enhance reliability performance, enhance customer awareness and choice, and encourage greater efficiency decisions of the customer and of the utility provider. (Forte 2010)

2. THEORETICAL BACKGROUND

2.1 Building Energy Information Modeling (BEIM)

Building Information Modeling (BIM) can bridge the information loss associated with handling a project from design team to construction and to building owner/operator, by allowing each group to add to and reference back to all information they acquire during their period of contribution to the BIM model. This can yield benefits to the facility owner or operator. Dynamic information about the building, such as sensor measurements and control signals from the building systems, can also be incorporated within BIM to support analysis of building operation and maintenance. (Wikipedia 2013, Xuesong Liu 2009)

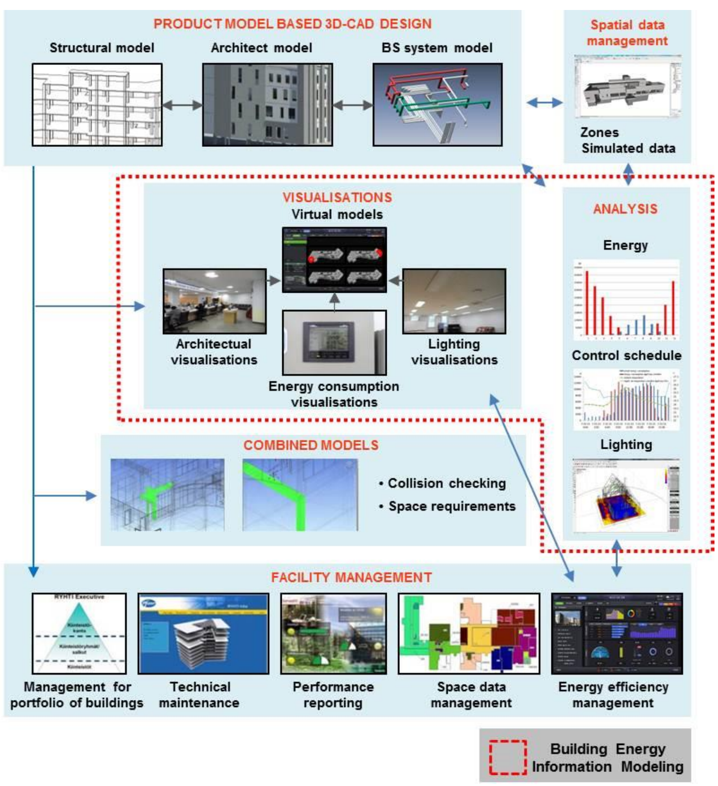

Figure 1: Concept of the BEIM (Lee 2013)

By using BIM it is easier to verify thermal performance truly in different phases of the building process. The experiences from many BIM based projects show that interoperable thermal analysis software is not enough for the management of thermal performance during the building process, but it requires also tools to manage different revisions of BIM, to compare thermal performance of these revisions and to visualize this by easy-to-understand way. (Laine et al. 2007)

Figure 1 shows set up of BEIM. In this paper, BEIM (Building Energy Information Modeling) was used as two role, one is visualization of measured environmental data, the other is to support analysis about building simulation (such as energy analysis, life cycle cost, CFD, etc.). Through using these roles of BEIM, BEIM was used as 3D- Model about energy information at GUI of energy management system. Using analysis of building energy simulation based on BEIM, energy saving method of building facilities could be sought. (Lee et al. 2013)

2.2 Building energy simulation

Whole building simulation is increasingly used I the design of building Heating, Ventilating and Air-Conditioning (HVAC) systems but is seldom used subsequently to optimize operation of building. Use of whole building simulation for optimization is conceptually most practical in cases where a simulation has already been performed as part of the design process or as part of retrofit evaluation. The input values for the existing simulation may then be used to predict building performance and explore opportunities for optimization; likewise, if the operation has been optimized, deviation will indicate the need for investigation to bring the building back to optimum operation. However, the specific comparisons that can be performed will be dictated by the capabilities of the simulation model and by the performance data available for comparison with the simulation. If Building Energy Management System (BEMS) data will be used for comparison with the simulation, appropriate energy consumption sensors must be available on the BEMS. (Hensen and Lamberts 2011)

In this study, building energy simulation program is used to find energy saving method for test bed. For this, building energy simulation program was connected with Genetic Algorithms (GA) as optimization techniques.

2.3 Genetic Algorithms (GA)

Genetic algorithms (GA) is search algorithms based on the mechanics of Darwin's natural selection. They combine survival of the fittest among string structures, with a structured yet randomized information exchange, to form a search algorithm that has some of the innovative flair of human search. Since their introduction by Holland, GA has been applied to a diverse range of scientific engineering and economic search problems. (Huang and Lam1997)

GA differs from the traditional methods of optimization in the following respect:

- A population of points is used for starting the procedure, instead of a single design point. If the number of design variables is n, the size of the population is usually taken as 2n to 4n. Since several points are used as candidate solutions, GA is less likely to get trapped at a local optimum.
- GA uses only the values of the objective function. Derivatives are not used in the search procedure.
- The objective function value, corresponding to a design vector, plays the role of fitness in natural genetics. (Rao 2009)

Figure 2 shows the Concepts of GA. GA is based on the principles of natural genetics and natural selection. The basic elements of natural genetics - reproduction, crossover and mutation - are used in the genetic search procedure. (Han 2009)

In this paper, GA is used to optimize HVAC energy consumption in test bed. Through controlling supply air temperature of HVAC, building energy consumption was able to be optimized. So GA was applied to simulation model of test-bed for control schedule of supply air temperature in test bed

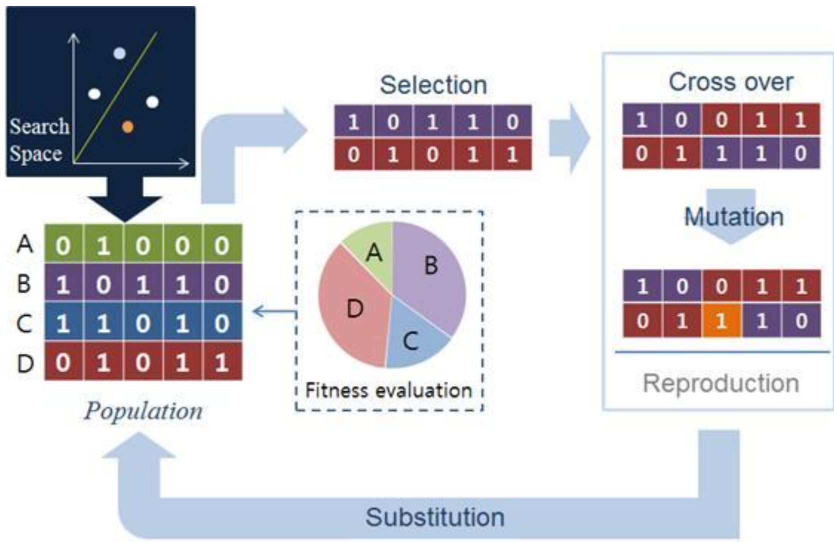

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Figure 2: Concept of Genetic Algorithms (Han 2009)

3. INFORMATION OF TEST BED

3.1 Selected office building

First town complex community center is a four-floor 4,635.1m^2 building housing a health center and a community center in Se-jong as shown in Figure 3. It consists largely of office, there are some class room and an auditorium. First town complex community center receives hot water and chilled air from Plant at underground machine room for its HVAC system. Its HVAC system is a single dual-duct constant air volume

Figure 3: View of test bed

Figure 4: BIM data of test-bed

Figure 4 shows BIM data of test-bed. BIM included various information of building. so using BIM data of test-bed, building simulation can be implemented. For using BIM at building simulation A visualization of environmental data can be also established in energy monitoring system.

Building Energy Management System (BEMS) was constructed at this building, so environment data, such as weather data, indoor temperature, energy usage, outdoor temperature and indoor setting temperature) were measured and corrected in real time at Energy Operating Center(EOC). There are three buildings where BEMS was constructed excepted First town complex community center.

3.2 Energy Operating Center (EOC)

All the data from the four buildings are transmitted to Energy Operating Center(EOC). There is monitoring system including Graphic User Interface (GUI) which can be monitored and controlled by operator. As Wikipedia(2013), in computing, GUI is a type of user interface that allows users to interact with electronic devices using images rather than text commands.

GUI is useful because it makes a user easily to understand the computer system. For that reason, GUI was developed and applied for energy management. Figure 5 shows GUI screen of EOC. First picture shows energy consumption of each floor and distribution ratio of energy consumption. Second picture does energy consumption of each building. There are energy consumption data of four building in test-bed. Test-bed was included in these four building. Using this second screen, general energy consumption was confirmed. The last picture shows energy consumption for a day and environmental data. Through this GUI screen, Environmental data, such as energy usage, indoor/outdoor temperature, was visualized. Therefore, an operator in EOC and users can easily understand and control energy usage.

Figure 5: GUI screen of Energy Operating Center

4. CONTROL METHOD OF TEST BED

4.1 Optimization of building energy consumption based on GAs

In this study, Building Information Modeling(BIM) was used to simulate building energy consumption. BIM includes building information that was needed at building simulation. If BIM was used for building simulation, a few step was required. First of all, BIM was converted to gbXML. The gbXML schema was developed by Green Building Studio (formerly Geopraxis) with the support of the California Energy Commission Public Interest Energy Research (PIER) Program, and the California Utilities (Pacific Gas and Electric Company, Southern California EDISON and Sempra Energy Utility). gbXML currently facilitates the exchange of data among CAD and energy analysis software. Several popular CAD software (e.g., Autodesk's Revit, Architectural Desktop, and Graphisoft's ArchiCAD) and energy analysis applications (e.g., DOE-2. e-QUEST, HAP) can exchange data using this schema, through the Green Building Studio web service .(Dong et al. 2007)

But gbXML could not be applied to Energyplus (one of building energy simulation program). So gbXML was converted idf file format in Design Builder. The Idf file format is EnergyPlus model input file. Building energy simulation on test bed was implemented using idf file format.

Figure 6 shows Method of energy optimization using GA. In this study, GA was used twice. For the first time, GA was used to calibrate building simulation setting. At next stage, GA was used to optimize HVAC control for the second time.

There were difference between Building energy simulation and measured values. So parameters of building energy simulation setting should be calibrated. And then the calibrated Heating, Ventilating and Air-Conditioning (HVAC) simulation setting was used to find supply air temperature schedule every hour. The target parameter is supply air temperature. So Initial Population was supply air Temperature and Fitness function was calibrated building simulation model of test-bed

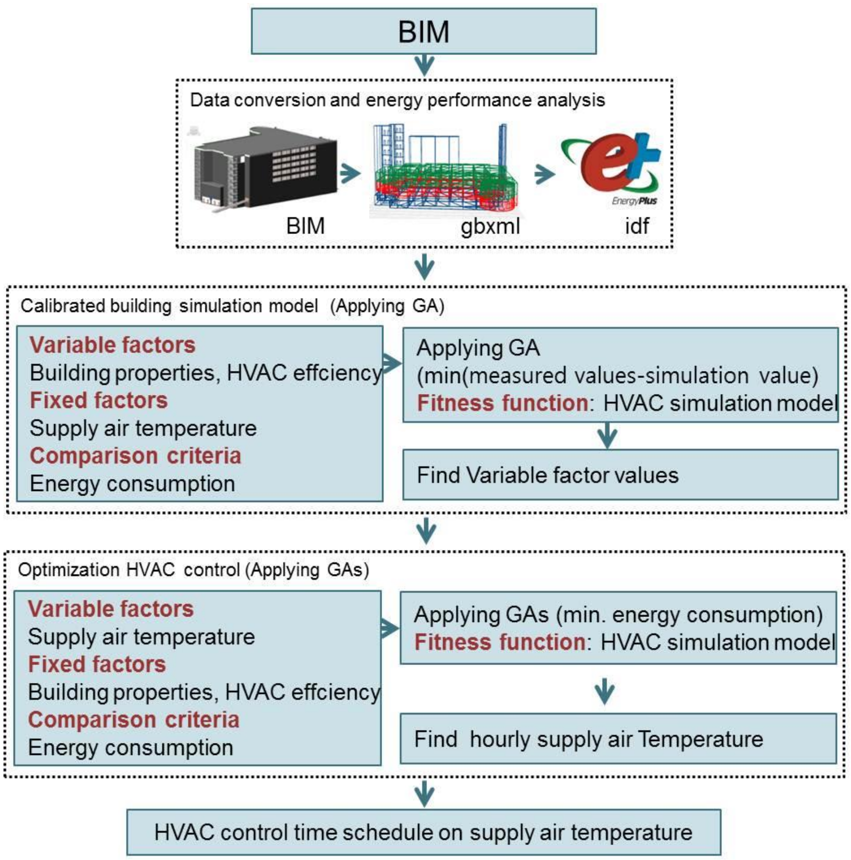

Figure 6: Method of energy optimization using GA

In a process to find out how to operate in maximizing both the indoor condition and saving-energy, GA is utilized. At simulation test, energy saving effect was approximately 5%. HVAC control time schedule of supply air temperature was saved at data base server in EOC for applying to control system and monitoring system.

4.2 Optimal control strategy of Heating, Ventilating and Air-conditioning (HVAC)

By that system, it is expected that unnecessary energy usage will be reduced much (refer figure 7). In other words, in door environment conditions such as indoor temperature, indoor setting temperature and energy consumption are monitored and visualized through using BEIM. The system which simulate building energy consumption using BEIM and GAs determines how operate facilities such as HVAC. HVAC control time schedule was applied to GUI of monitoring system. Through information of optimizing schedule, the BEMS of test-bed was controlled by operator

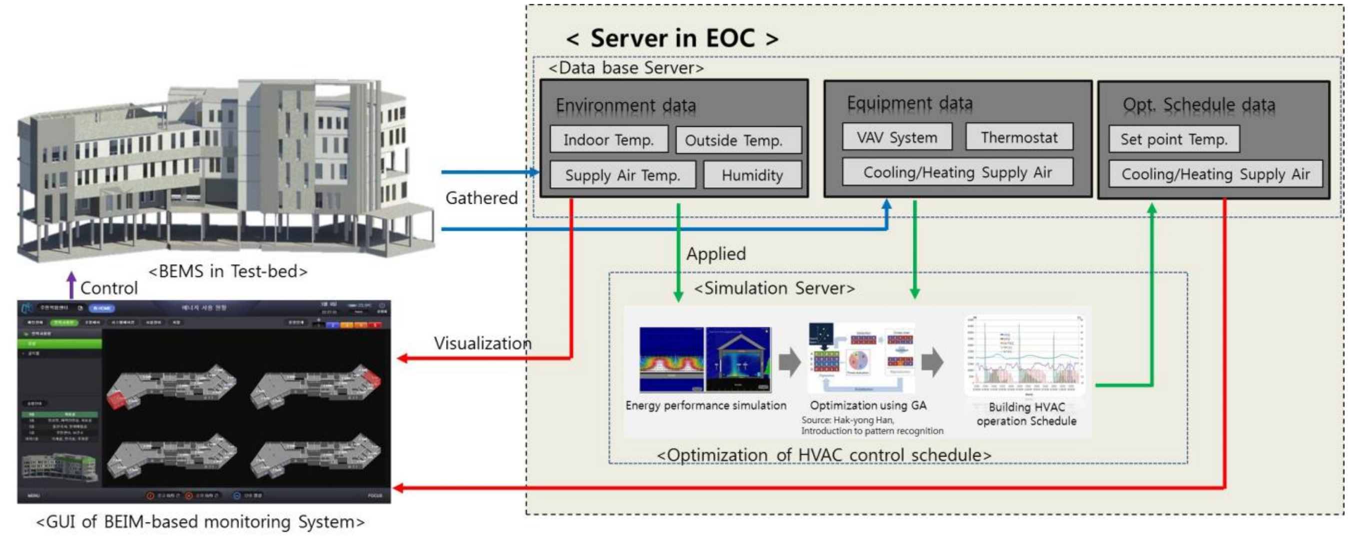

Figure 7: BEIM-based monitoring system

5. CONCLUSION AND FUTURE WORK

Energy-saving efforts have recently become a high-priority interest against global climate change. Numerous high energy efficiency equipment devices are being developed to save building energy consumption. Energy management and operation methods are also important for the optimization of the building energy consumption. To tackle this issue, BEIM-based energy simulation and building energy monitoring were proposed to optimize the HVAC energy consumption.

Especially, the energy saving technologies using real time energy consumption monitoring system and energy simulation based optimization were investigated. To validate this approach, five buildings where BEMS and Smart Grid are constructed were taken, and the environmental data and energy consumption were measured and gathered. These data was applied to analyze building environment and simulate building energy consumption.

Furthermore, four public buildings including complex community center were recently managed at operating center. Each building is currently controlled by a designated manager at this center. Many environmental data were also gathered from the sensors installed in these buildings. Through simulating test-beds using this information, energy saving method to control HVAC system in test-beds was successfully verified. If the aforementioned project would be completed successfully, these technologies will be applied over the whole of Sejong city. It is expected that this research on energy optimization using BEIM would play a vital role for the near future Korea micro energy grid projects.

ACKNOWLEDGMENTS

This work is financially supported by Korea Minister of Ministry of Land, Transport and Maritime Affairs(MLIM) as 「U-City Master and Doctor Course Grant Program」 and the Korea Micro Energy Grid (K-MEG) of the office of Strategic R&D Planning (OSP) grant funded by the Korea Government

Ministry of Knowledge Economy (NO. 2011T100100022). Their complete support is greatly appreciated.

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