Whole Building Energy Performance Evaluation through Similar Control Strategies

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ABSTRACT

The energy consumption of architectural environment system accounts for the most proportion in life cycle cost, and it can be efficiently reduced through Building Automation System(BAS) based on Building Energy Management System(BEMS). There are similar controls among the BAS control strategies. However, there are almost no studies that compare the building energy performance of such similar controls. Accordingly, this study compares and analyzes the building energy performance of similar controls and then decides which control strategy appears to derive the most benefit during cooling season.

The real target building model is modelled by using EnergyPlus and verified through comparing the actual energy consumption with the simulated energy consumption. After that, temperature control and enthalpy control which are to manipulate the outdoor air flow rate by comparing the thermal properties of return air are applied to verified model. In addition, the zero energy band and duty cycling are performed to determine the operational status of AHU by measuring indoor temperature. Results shows that the enthalpy control is more beneficial than the temperature control, and the duty cycling is more reliable than the zero energy band. According to the result of this study, it is found that it is better to apply the control that is good building energy performance in the similar control strategies.

In the design phase, the control that is good building energy performance in the similar control strategies can be preferentially selected, and, furthermore, they can be integrated into one.

KEYWORDS

Building Automation System, Temperature Control, Enthalpy Control,
Zero Energy Band, Duty Cycling

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INTRODUCTION

In life cycle cost(LCC), the energy cost and facility management cost during the operational phase is five to six times higher than the initial investment cost. Because the energy consumption during the operational phase of the building accounts for a large proportion, its importance, related to the efficient use of energy in building operation and management aspect, increases. Studies related to building energy management system(BEMS) that includes building energy management functions have been internationally conducted with building automation system(BAS) that includes control facilities to use energy efficiently.

Kim et al.(2010) studied the change of cooling load through applying temperature control and enthalpy control to the office building located in Seoul. The enthalpy control caused the cooling load to reduce. However, the temperature control increased the cooling load due to the excessive increase of latent heat load based on the characteristics of Korean summer climate. Huang et al.(2006) applied optimum start/stop, night purge, and enthalpy control to virtual zone developed on the VAV system and reported energy saving of 17%. Canbay et al.(2006) applied optimum start/stop, night purge, and enthalpy control to shopping centre buildings in Turkey and reported energy saving of 22%.

There are similar controls among the BAS control strategies. However, there have been almost no studies comparing the building energy performance of such similar controls. In the design phase, the control that is good building energy performance in the similar control strategies can be preferentially selected, and, furthermore, they can be integrated into one.

This study compares and analyzes the building energy performance of temperature control and enthalpy control as outdoor air control strategies, and zero energy band and duty cycling as AHU control strategies during cooling season.

METHOD

This study is performed by using the following procedure, and uses EnergyPlus as an energy simulation tool.

(1) Modelling through the energy audit of the target building.

(2) Completion of the baseline model through comparing the simulated energy consumption with the actual energy consumption.

(3) Application of outdoor air control strategies(e.g., temperature control and enthalpy control) and AHU control strategies(e.g., zero energy band and duty cycling) to the baseline model.

(4) Comparing and analyzing the building energy performance of the similar control strategies.

MODELING AND CALIBRATION

The office building, G Building, located in Daejeon, Republic of Korea, is composed of five floors. It uses the VAV system for air conditioning, and operates four air handling units(AHUs). The operational status of its AHUs is shown in Table 1.

Table 1.*Operational status of AHUs*

Items	*Heat Source of Coils*	*Etc.*
AHU 1	Using plant	Conditioning with EHP
AHU 2		
AHU 3	Using electricity	-
AHU 4	Using plant	Disuse

The simulated energy consumption is compared with the actual energy consumption of the chillers, cooling tower, EHP, fans, pumps, lighting, and plug that is measured to calculated monthly error. Since this study analyzes the building energy performance of similar controls during cooling season, the energy consumptions from July to December are considered. Input values are adjusted after analyzing causes when error occurs greatly. The calibration process of model is shown in Figure 1.

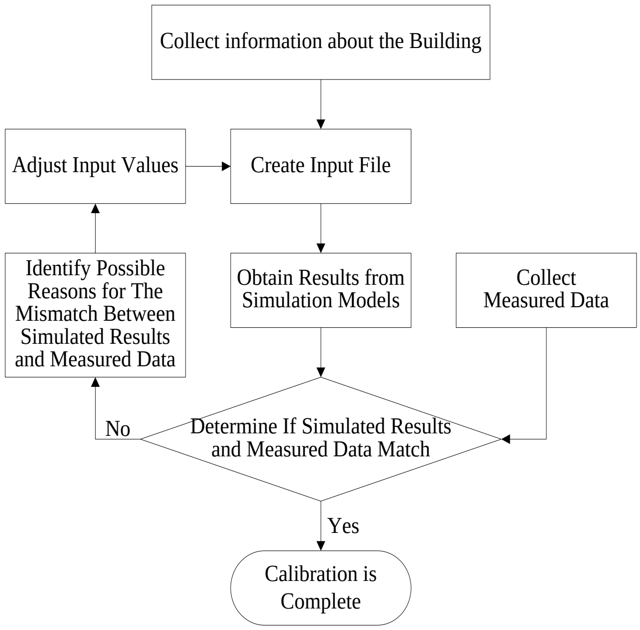

Figure 1. *Calibration process of Model*

The error is calculated by using the Mean Bias Error (MBE) Eq. (1), Root Mean Square Error (RMSE) Eq. (2), and Coefficient of the Variation of RMSE (Cv(RMSE)) Eq. (3).

$$MBE(\%) = \frac{\sum_{Period}(S-M)_{Interval}}{\sum_{Period} M_{Interval}} \times 100 \tag{1}$$

$$RMSE_{Period} = \sqrt{\frac{\sum_{Period}(S-M)_{Interval}^{2}}{N_{Interval}}} \tag{2}$$

$$Cv(RMSE_{Period}) = \frac{RMSE_{Period}}{A_{Period}} \times 100 \quad (3)$$

where S, M, N, and A are the simulated energy consumption[kWh], measured energy consumption[kWh], number of data, and mean of the measured energy consumption[kWh], respectively.

Each MBE and Cv(RMSE) value in the results is shown in Table 2. The MBE and Cv(RMSE) values of the target building model are satisfied with the recommended error standard(ASHRAE 2002, M&V 2008). The completed baseline model is shown in Figure 2.

***Table 2**. MBE and Cv(RMSE) values*

Items	*MBE [%]*	*Cv(RMSE) [%]*	*Items*	*MBE [%]*	*Cv(RMSE) [%]*
Chiller	-2.32	5.43	Pump	0.44	13.53
Cooling tower	1.89	9.86	Lighting	-3.23	12.19
EHP	4.07	12.31	Plug	-1.35	7.71
Fan	-4.79	10.80	Total	-1.75	4.84

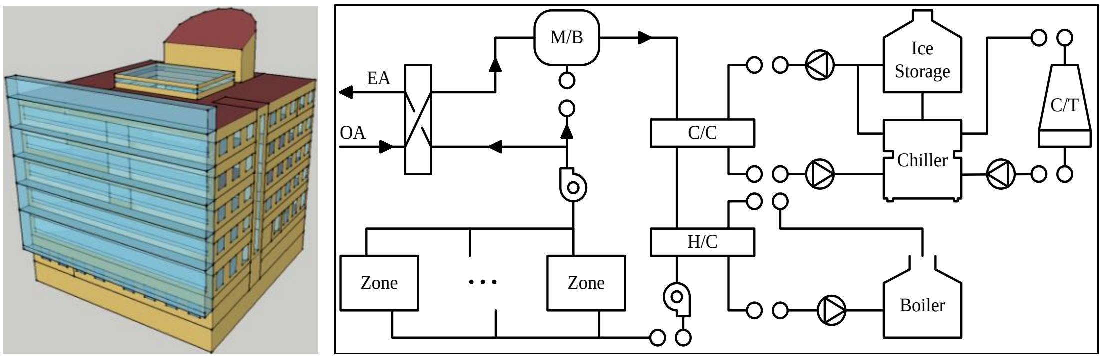

***Figure 2.**Whole building simulation modeling*

CONTROL STRATEGIES

(1) Outdoor Air Control Strategies
Temperature control and enthalpy control compare the thermal properties of return air and outdoor air. The outdoor air flow rate is increased if the thermal property of outdoor air is more beneficial to air conditioning than return air, or the outdoor air flow rate is minimized if it is not. Therefore, the thermal property of mixed air that is beneficial to air conditioning is induced to reduce the load of coils and facility. Temperature control considers only sensible heat of air, while enthalpy control considers both sensible heat and latent heat of air.
This study applies temperature control and enthalpy control by using Erl(EnergyPlus runtime language). The composed algorithms are shown in Figure 3 and 4 respectively.

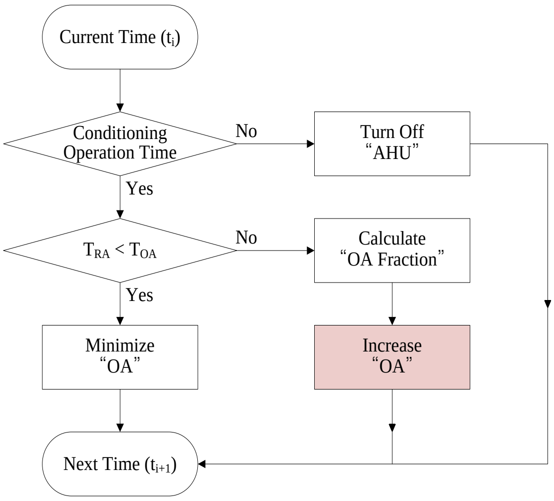

Figure 3. *Temperature control*

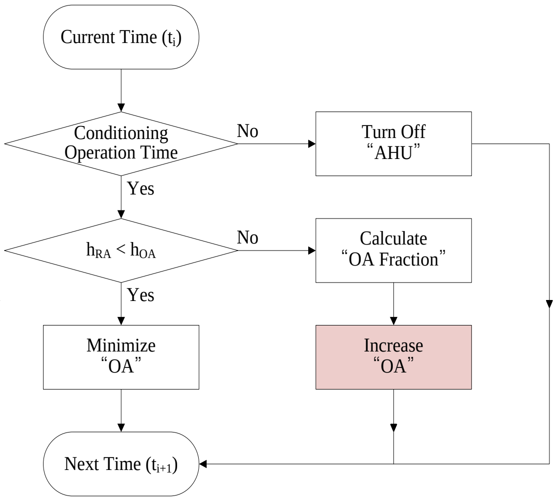

Figure 4. *Enthalpy control*

(2) AHU Control Strategies

Zero energy band is a dead band where neither heating nor cooling energy is used within the time of air conditioning. The main purpose is to minimize the energy consumption of AHU by stopping air conditioning when the indoor temperature is within the zero energy band.

This study excludes winter season, and the permitted maximum temperature is set as 28℃ that is the set point of the target building. The algorithm is composed by using Erl. The composed algorithm is shown in Figure 5.

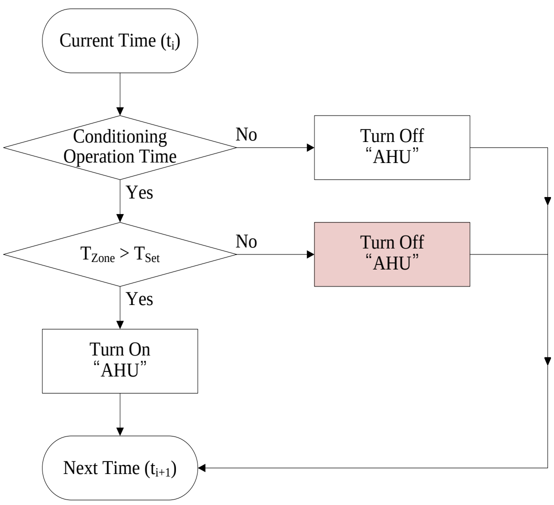

Figure 5. *Zero energy band*

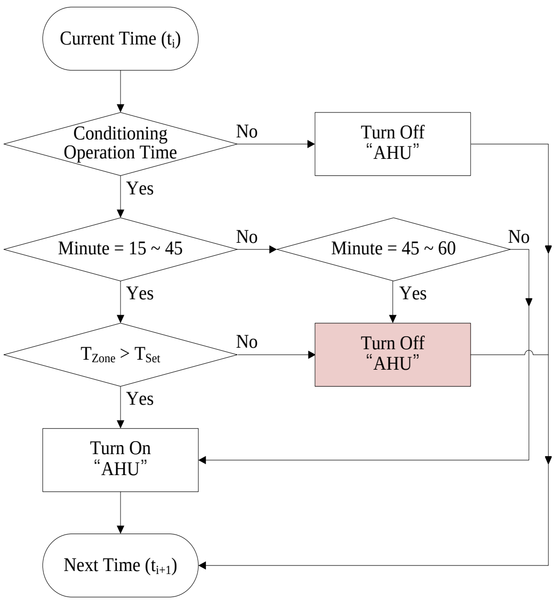

Figure 6. *Duty cycling*

Duty cycling is very similar to zero energy band. However, there is a difference due to the fact that the stop time is determined to meet the indoor condition of each specific cycle. The actual stop time is adjusted by using the feedback of the indoor temperature between the pre-set minimum and maximum stop time to maintain the comfortable indoor condition.

This study sets that the feedback period is from 15minute to 45 minute and minimum stop time is 15minutes 45minute to 60 minute within a cycle per hour. The algorithm is composed by using Erl, and shown in Figure 6.

RESULTS AND DISCUSSION

In this study, the total electric energy consumption(Cooling energy) of the chillers, cooling tower, EHP, and DX coil that is used to remove cooling load is considered during cooling season(from July 1 to September 18). The cooling energy of each case is shown in Figure 7.

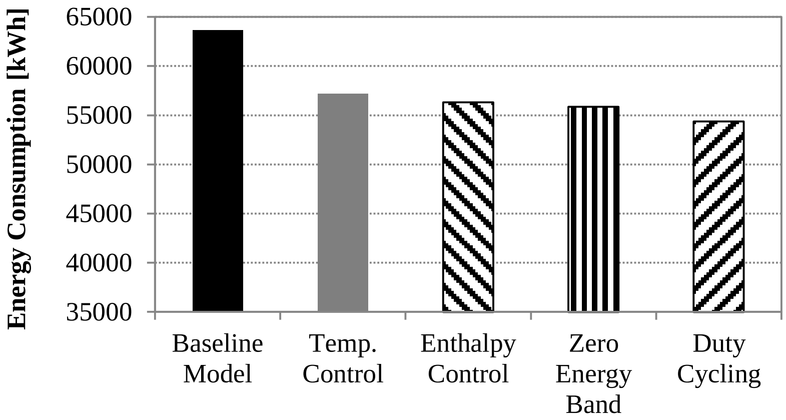

***Figure 7**. Cooling energy of each cases*

(1) Outdoor Air Control Strategies

Cooling energy saving is 6,473 kWh(10.2%) in the temperature control, and 7,302 kWh(11.5%) in the enthalpy control in comparison to the baseline model. The cooling energy is reduced in both controls by increasing the outdoor air flow rate when it is beneficial to air conditioning, and it is analyzed that the cooling energy saving of the enthalpy control is greater than the temperature control due to the characteristics of the Korean summer humid climate.

(2) AHU Control Strategies

Cooling energy saving is 7,741 kWh(12.2%) in the zero energy band, and 9,264 kWh(14.6%) in the duty cycling in comparison to the baseline model. Both controls usually stop AHUs for 15 minutes to 30 minutes within an hourly cycle. However, the zero energy band sometimes keeps operating AHUs without stop while the duty cycling stops AHUs for at least 15 minutes, thus, it is analyzed that the cooling energy saving of the duty cycling is greater than the zero energy band.

CONCULSION

This study develops the baseline model of the target building through comparing the simulated energy consumption with the actual energy consumption by using the energy simulation tool to apply control strategies. As similar control strategies, the building energy performance between temperature control and enthalpy control, and between zero energy band and duty cycling are comparatively analyzed. The results show that all controls cause the cooling energy to reduce in comparison to the baseline model. It is analyzed that the cooling energy saving of the enthalpy control is greater than the temperature control, and the cooling energy saving of the duty cycling is greater than the zero energy band.

This study is expected to be used as basic data, in the selection of a control strategy, which is good building energy performance in the design phase, and in the use of the integration of similar controls as a single control mechanism. However, advanced study should be conducted to apply to actual buildings since this study conducts by using only the energy simulation tool.

ACKNOWLEDGEMENT

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