ENERGY SAVING EFFECT OF THE ERV (ENERGY RECOVERY VENTILATOR) WITH OUTDOOR AIR COOLING

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ABSTRACT

Maintaining an IAQ with fresh in school building is very important because the good IAQ can keep the student in health and improve the academic performance. Since school buildings are very dense and require a lot of fresh air, the need for ventilation has become obvious. While opening a window does provide fresh air, which is undesirable for the indoor climate and for energy efficiency under severe outdoor condition. ERV (Energy Recovery Ventilation) technology offers an optimal solution: fresh air, better climate control and energy efficiency. However, when the outdoor air condition is favourable to control the indoor environment such as spring and autumn in Korea, heat exchange in ERV would rather increase the cooling load than diminish. Economizer cycle control which using the outdoor air in controlling the indoor thermal environment has many benefit in terms of energy saving and IAQ control.
In this study, the ERV with outdoor air cooling mode is suggested. And then the system control characteristics and energy saving effect were analyzed using the simulation method.

KEYWORDS

ERV, Outdoor air cooling, Energy saving, TRNSYS

1 INTRODUCTION

Good Indoor Air Quality (IAQ) of school buildings is an important factor to maintain healthy indoor environments and to improve the student's academic performance. Because the population density of the school is high and the students spent a long time in class. Poor indoor air quality can cause many adverse health effects such as respiratory symptoms, asthma (Mi et al., 2006). The ventilation requirement in school buildings is specified in the "School Health & Hygiene Law" in Korea. School buildings should be ventilated at the air flow rate of more than 21.6 [CMH/person] by opening the windows or operating mechanical ventilation systems (Lee YG, 2008).
However, introducing the outdoor air for ventilation results in increased heating and cooling demands in sever outdoor condition. Energy Recovery Ventilators (ERV) is a good solution in

conflicted interests between ventilation and energy saving. ERV have been equipped in most of the newly constructed school building in Korea from 2007. ERV, however, occasionally rather results in the increase of the cooling load because unnecessary heat recovery makes the cool and comfort outdoor air into hot and discomfort air.

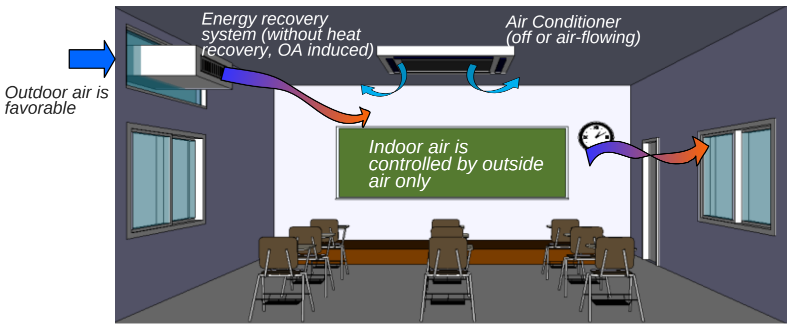
In this study, the ERV with outdoor air cooling or economizer cycle is suggested. And the energy saving effect of the proposed system was analyzed by simulation method. In this paper, the system configuration, the system control characteristics and energy saving effect of the proposed system were described.

2 OUTLINE OF THE ERV WITH OUTDOOR AIR COOLING

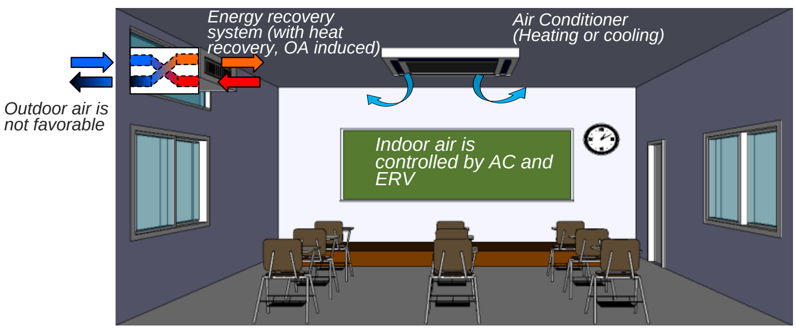
2.1 System configuration

This system consists of the ceiling mounted air-conditioner (VRF, Variable Refrigerant Flow) and ERV (Energy Recovery Ventilator) with economizer cycle. It is similar to the previous VRF air conditioner with ERV (here after, VRF AC+ERV) in system structure, but the control logic for ERV is different in both systems. The ERV with economizer cycle is controlled based on the outdoor air condition. Economizer cycle control (Ke and Mumma, 1997) is a method to control the indoor environment using the outdoor air by introducing outdoor air without heat recovery when the outdoor air temperature or enthalpy is lower than that of the indoor set-point. The economizer cycle control can be categorized as 'temperature based control' and 'enthalpy based control' depending on its control method generally used for HVAC system.

The proposed system (VRF AC+ERV with economizer cycle) is operated like the previous "VRF AC+ERV" when the outdoor conditions are not favourable as shown in Fig. 1-(b). In this condition, the outdoor air is wholly induced with heat recovery, and VRF AC is operated for cooling or heating. However, when the outdoor conditions are favourable, the outdoor air is induced directly without heat recovery, and used for cooling as well as improvement of IAQ (see Fig. 1-(a)).



(a) Economizer cycle control mode : The indoor air is controlled by outside air only



(b) AC + ERV mode : The outdoor air is introduced with heat recovery

Figure 1: System outline

2.2 System control logic

Fig. 2 shows the logic of "VRF AC+ERV with economizer cycle". When the outdoor air condition is comfortable, outdoor air is induced without heat recovery at the maximum ventilation rate through ERV as shown on phase 1 . In this condition, indoor thermal environment is controlled by the outdoor air. On the while, outdoor air is induced through heat recovery at the minimum ventilation rate when the outdoor condition is not favorable. In phase 2 , AC is operated for cooling when indoor air temperature is higher than *Tiset*, and it stops when indoor air temperature is lower than *Tiset*.

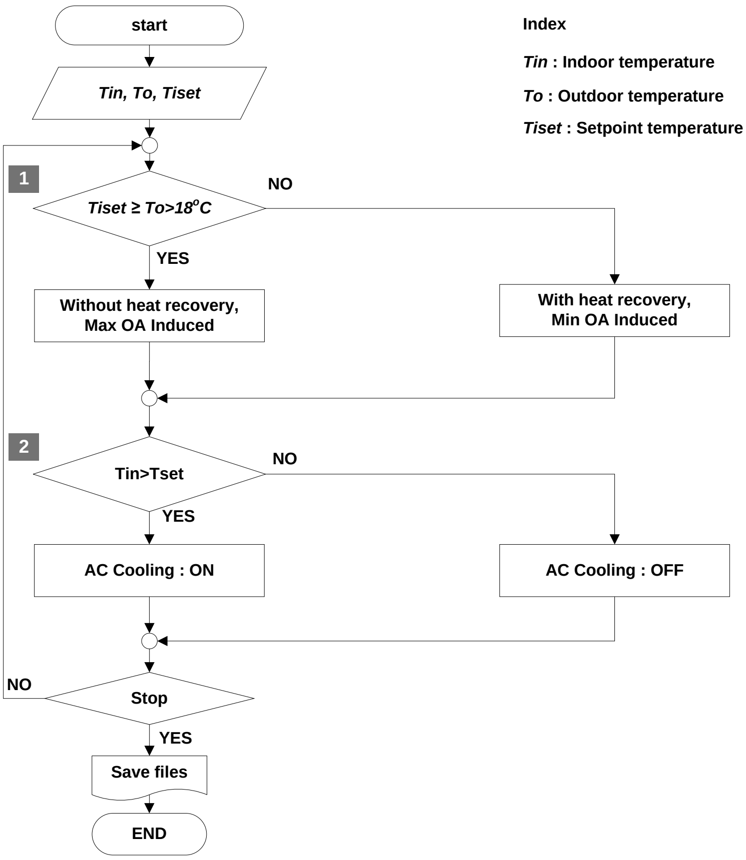


Figure 2: System control logic

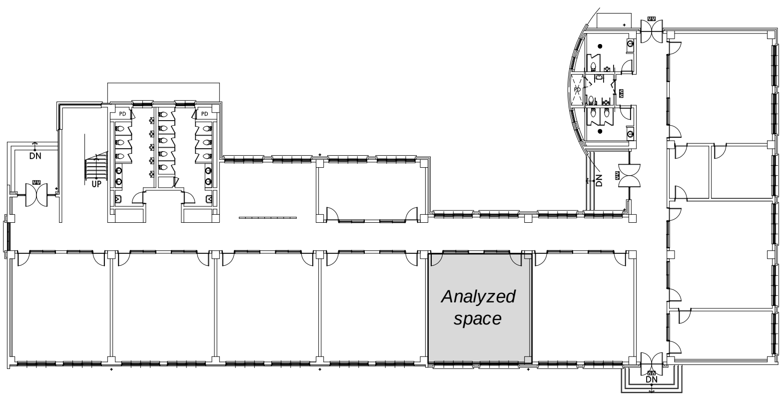


Figure 3: Analyzed space

3 ANALYSIS OF THE INDOOR CONTROL AND ENERGY CONSUMPTION BEHAVIROS

3.1 Simulation conditions

The analyzed school building was a J high school located at Gimpo, Korea, and the classroom is on the second floor in the middle of the school building with the size of 67.24 m^2. Table 1 shows the simulation conditions. The capacity and electricity consumption data of AC and ERV systems installed in the analyzed classroom are described in Table 2 and 3.

Table 1: Simulation Conditions

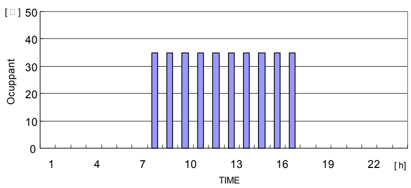
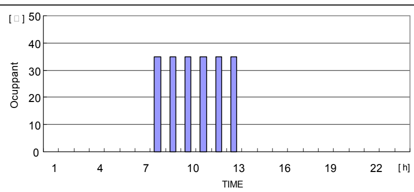
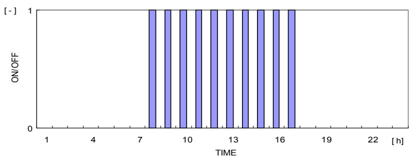
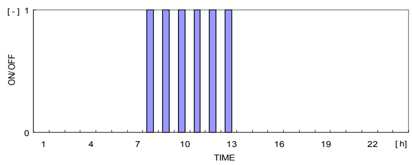
Weather data		Seoul, Korea (TMY2)	
Heating set point		22 ^oC (dead band 1 ^oC)	
Cooling set point		26 ^oC (dead band 1 ^oC)	
Heat gain	Persons	▪ Occupants : 35 Person ▪ Activity level : Seated, very light writing ▪ Internal Heat Gain : Sensible heat 65(W), Latent heat 55(W) ▪ Occupancy Schedule	
		 Weekday	 Weekend
	Lighting power	▪ Density : 15 (W/m^2) ▪ Schedule	
		 Weekday	 Weekend
Air-flow rate of ERV		800 (CMH)	
System operation schedule		Weekday 08:00 ~ 17:00 (on), other hour (off) Saturday 08:00 ~ 13:00 (on), other hour (off) Sunday and holiday (off)	

Table 2: VRF AC System information

		Max	Min
Performance	Capacity (HP)	5	
	Cooling (Kcal/h)	12,470	
	Heating (Kcal/h)	14,020	
Air flow rate (CMM)		29	19.33
Electrical demand	Outdoor unit (W)	7,192	7,109
	Indoor unit (W)	85	10

Table 3: ERV System

Air Flow rate (CMH)			800
Electrical demand (W)			290
Heat recovery performance (%)	Sensible heat	Cooling	71
		Heating	82
	Latent heat	Cooling	44
		heating	65

Table 4: Simulation Cases

Cases	Operation mode
Case 1	AC + mechanical ventilator
Case 2	AC + ERV (Normal control)
Case 3	AC + ERV (Economizer cycle control)

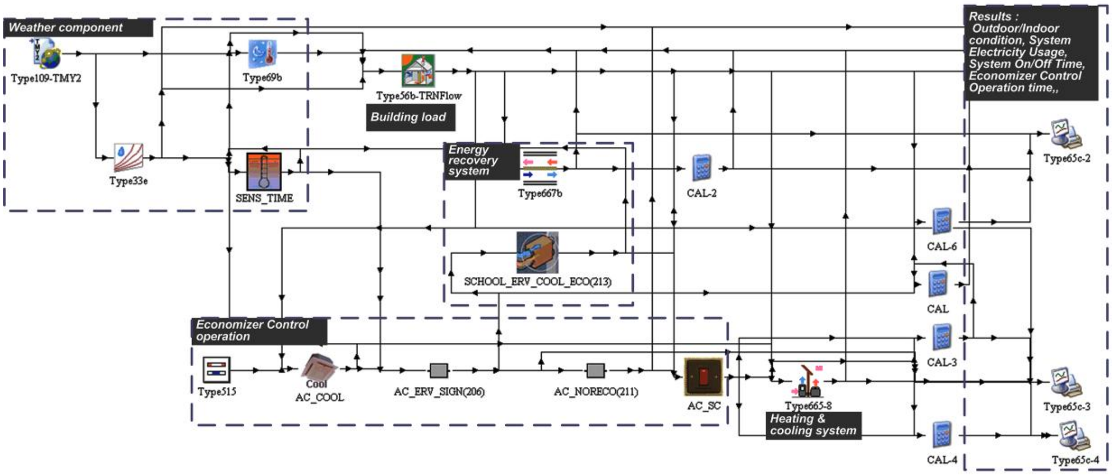


Figure 4*:* Layout of economizer control with AC and ERV in TRNSYS

Fig. 4 depicts the layout of the simulation modeling by TRNSYS. A module provided by the TRNSYS program was used for weather conditions, indoor temperature condition setting, building modeling, AC and ERV system modeling, and energy consumption output module for the simulation (TRNSYS, 2007).

However, the system control modules such as economizer cycle control and AC and ERV system control module were newly developed for the simulation of this study.

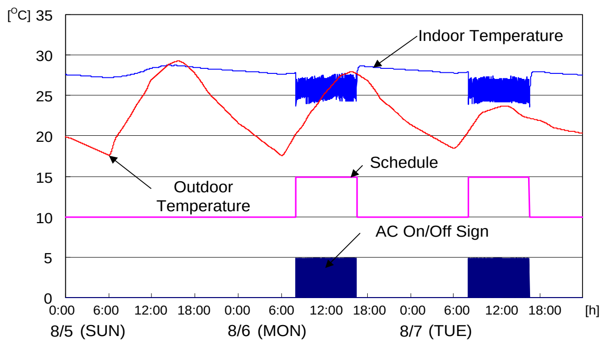
Table 4 shows the simulation cases analyzed in this study. In Case 1, the classroom is equipped with AC and mechanical ventilator. In Case 2, the classroom is equipped with AC and ERV, and the ERV is controlled with normal control (heat recovery only). In Case 3, the proposed system in this study, the classroom is equipped with AC and ERV, and the ERV is controlled with heat recovery mode and outdoor air cooling (economizer cycle) mode.

3.2 Results

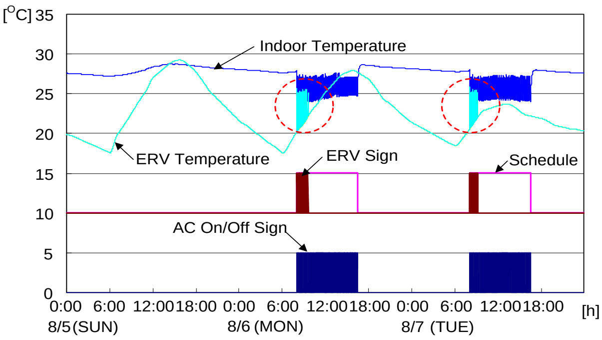
The system control and energy consumption behaviours of the analyzed cases were analyzed.

3.2.1 System control behaviours

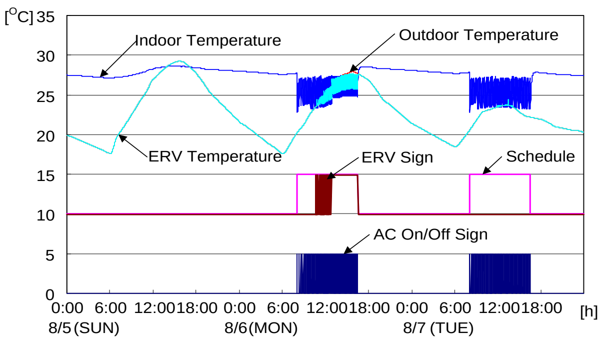
Fig. 5 shows the system control characteristics in the cooling period, and Fig. 6 shows that in the intermediate period.



(a) Case 1 (AC+Mechanical Ventilator)

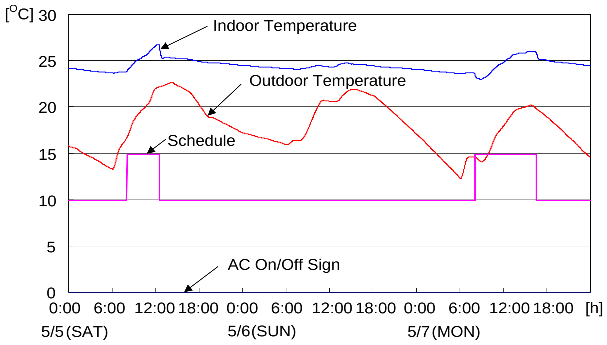


(b) Case 2 (AC+ERV)

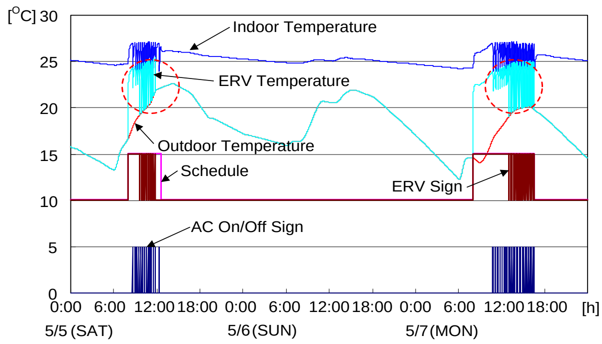


(c) Case 3 (AC+ERV with economizer control)

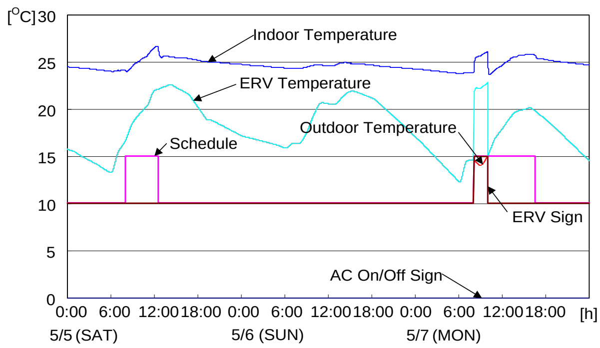
Figure 5: Cooling season control



(a) Case 1 (AC+Mechanical Ventilator)



(b) Case 2 (AC+ERV)



(c) Case 3 (AC+ERV with economizer control)

Figure 6: Intermediate season control

In cooling period (Fig. 5), the average indoor temperature was controlled by 26^{o}C in daytime in weekday. As shown in Fig. 5-(b), the temperature of the supply air from ERV was rather higher than that of the outdoor air temperature. This is because of the unnecessary heat exchange in ERV. This resulted in the increase in the operation hour of AC in Case 2.

In intermediate period (Fig. 6), also the temperature of the supply air from ERV was rather higher than that of the outdoor air temperature in Case 2 (Fig. 6-(b)).
In Case 3, the temperature of the supply air from ERV was same with the outdoor when the outdoor air was lower than indoor set-point temperature in cooling and intermediate season.

3.2.2 Energy consumption

Energy consumption was calculated from the operation hours of AC and ERV, and the monthly and annul electricity consumption of each case were estimated and analyzed.

Fig. 7 shows the monthly electricity consumptions of AC and ERV. In the heating period (November ~ March) of Case 1, the electricity consumption was the highest because the heating load was boosted by the induction of the outdoor air at low temperature. In Case 2 and 3, on the other hand, the great reduction in the electricity consumption of AC is observed because of ventilation through heat recovery.

In the intermediate and cooling period (April~October), the monthly electricity consumption of Case 3 which the outdoor air cooling (economizer control) was applied showed reduction compared to Case 1 and 2. While the energy consumption in Case 2 was higher than that in Case 1, which is the result of the increased indoor cooling load caused by the unnecessary heat exchange in ERV.

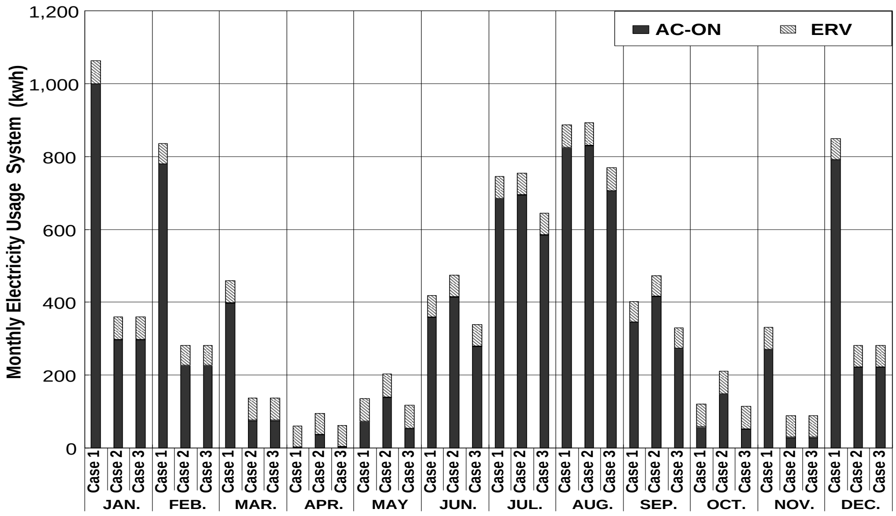


Figure 7: Monthly electric requirements for heating, cooling and ventilation

Fig. 8 represents the annual electricity consumptions of AC and ERV, showing the reduction in annual total electricity consumptions of the system by about 32.6% and 44.1% respectively in Case 2 and 3 compared to that in Case 1. With the outdoor air cooling mode in Case 3, the energy demand of AC was decreased by about 20.7% compared to that of the Case 2.

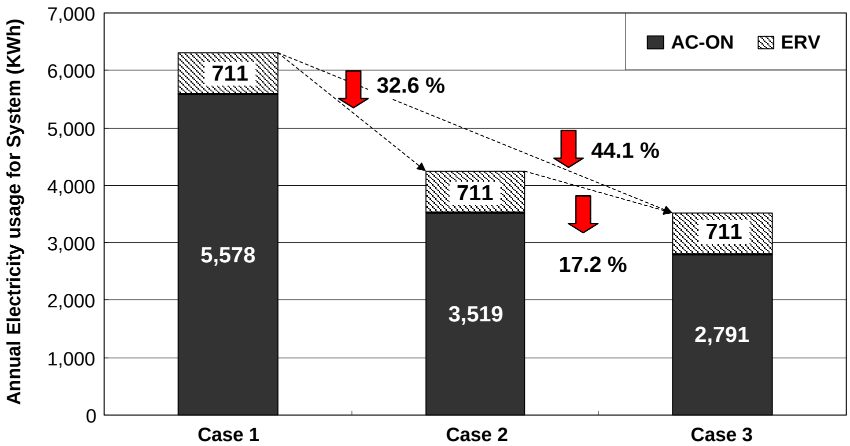


Figure 8: Annual electric requirements for heating, cooling and ventilation

4 CONCLUSIONS

In this study, the ERV with outdoor air cooling or economizer cycle is suggested. And the energy saving effect of the proposed system was analyzed by simulation method. The system control characteristics and energy saving effect of the proposed system were analyzed through the TRSNSYS simulation. The analysis results are as follows;

1) When operated by ERV with economizer cycle (Case 3), about 50% reduction in annual AC operation hour resulted compared to Case 1 (AC+ Mechanical ventilation, without heat recovery), and about 44.1% reduction in electricity consumption resulted. Compared to Case 2 (AC+ERV Normal control), about 20.7% reduction in annual AC operation hour and about 17.2% reduction in electricity consumption resulted.

2) AC+ERV with economizer cycle suggested by this study was verified as a method to minimize the energy consumption as well as to keep the indoor environment comfort and clean compared to the previous operation method of systems in the school buildings.

5 ACKNOWLEDGEMENTS

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