# Case studies on the Integrated Comfort Control for VRF and ventilation considering outdoor air conditions

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## ABSTRACT

This study aims to evaluate an Integrated Comfort Control (ICC) algorithm with an air conditioner, a humidifier, and a ventilator system by considering the outdoor environment to ensure indoor thermal comfort for occupants. For the performance evaluation, we have conducted experiments of two cases of cooling in a testbed. As a result, the integrated comfort control algorithm can control indoor conditions to reach within the comfort zone and maintain these conditions well.

## KEYWORDS

Integrated Comfort Control algorithm, Thermal comfort, Comfort control, VRF, Ventilation

## INTRODUCTION

As there is a growing demand for energy saving and thermal comfort in buildings, an integrated control of systems is becoming increasingly important. Earlier research has shown an Integrated Comfort Control (ICC) algorithm (Kim 2016), and confirmed that this algorithm has contributed to improved thermal comfort and energy efficiency by using Energyplus. However, the earlier research focused on the simulated condition, but it did not evaluate the application of a testbed. In this study, we conduct the experiment to examine an integrated comfort control algorithm in cooling in the testbed.

## METHODS

We suggested Comfort Control algorithm in earlier studies, which is to control conditions of the room air to reach the comfort zone with an air conditioner and humidifier. The comfort range in the cooling season was 24.4-26.5 °C dry-bulb temperature and 40-55% relative humidity. The Comfort Control algorithm is described in more detail (Yang 2013). The new Integrated Comfort Control algorithm is to add the ventilation system to the Comfort Control algorithm which is run by considering outdoor air conditions as well. The calculation of enthalpy difference between the indoor and outdoor air determines the optimum operation time of the

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ventilation system. After operating the ventilation system for calculated minutes, the air conditioner and humidifier proceed to run as defined in the comfort control algorithm. The Integrated Comfort Control algorithm is described in more detail (Kim 2016).

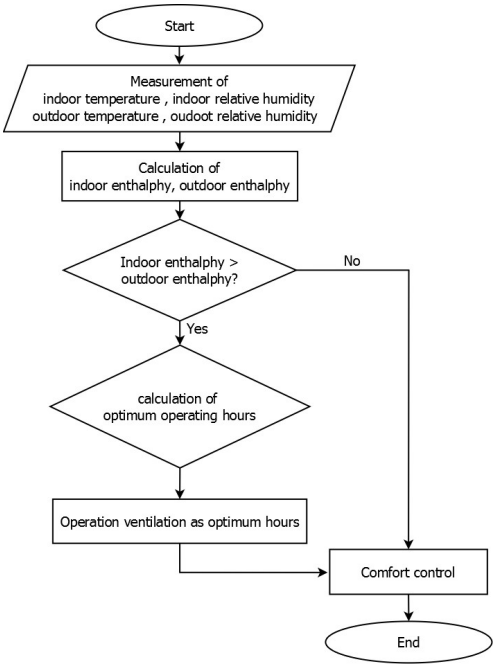


***Figure 1**. Flow chart of the integrated comfort control algorithm in cooling season*

For performance evaluation of the ICC algorithm was conducted in earlier studies based on simulation approach. In this study, we conduct experiments with the ICC algorithm in a testbed. The testbed is an enclosed chamber that consists of a variable refrigerant flow (VRF) system, a heat recovery ventilator, a humidifier, a dehumidifier, a floor heating system, a dimming system, automatic blinds, and a building monitoring system. These systems are interconnected using Building Automation and Control Networks (BACnet). BACnet is an ASHRAE, ANSI, and ISO 16484-5 standard protocol for building automation and control systems. The monitoring data is stored in the work station, and the data are used to decide control modes of the ICC algorithm.

***Figure 2**. Outside view of testbed*

***Figure 3**. Air-conditioning system, Ventilation system and humidifier in testbed*

We selected two experiment cases considering the condition of indoor air and outdoor air. The information of temperature and the relative humidity of cases are shown in table 1. In all cases, the ventilation system operated for 10 minutes before the VRF and humidifier started working when indoor air enthalpy was higher than outdoor air enthalpy. In fact, the operation time of the ventilation system should be calculated using an optimization method, but we set the operation time as arbitrary at this moment.

***Table 1.** Selected experiment cases*

| | Indoor air condition | | Outdoor air condition | |
|---|---|---|---|---|
| | Temperature(°C) | Relative Humidity(%) | Temperature(°C) | Relative Humidity(%) |
| Case1 | 32 | 35 | 26 | 50 |
| Case2 | 32 | 50 | | |

## RESULT

### Case 1

Figure 4 shows the results for the Integrated Comfort Control. In this case, the initial condition of the indoor air required cooling and humidifying. For the ventilation time, temperature was maintained at 32°C, and relative humidity increased by 0.6%. After the ventilation, the VRF and the humidifier were operated simultaneously. For the 48 minutes to reach comfort zone, the VRF was operated continuously. On the contrary, a humidifier was turned on and off repeatedly depending on the boundary of 40% relative humidity. After reaching the comfort zone, the VRF and the humidifier turned on and off repeatedly at around 26.5°C, and 40% humidity. As shown in figure 5, the conventional set temperature method (cooling only) did not reach the comfort zone

because the relative humidity did not reach 40%. This suggests that the Integrated Comfort Control method is much favorable in terms of thermal comfort.

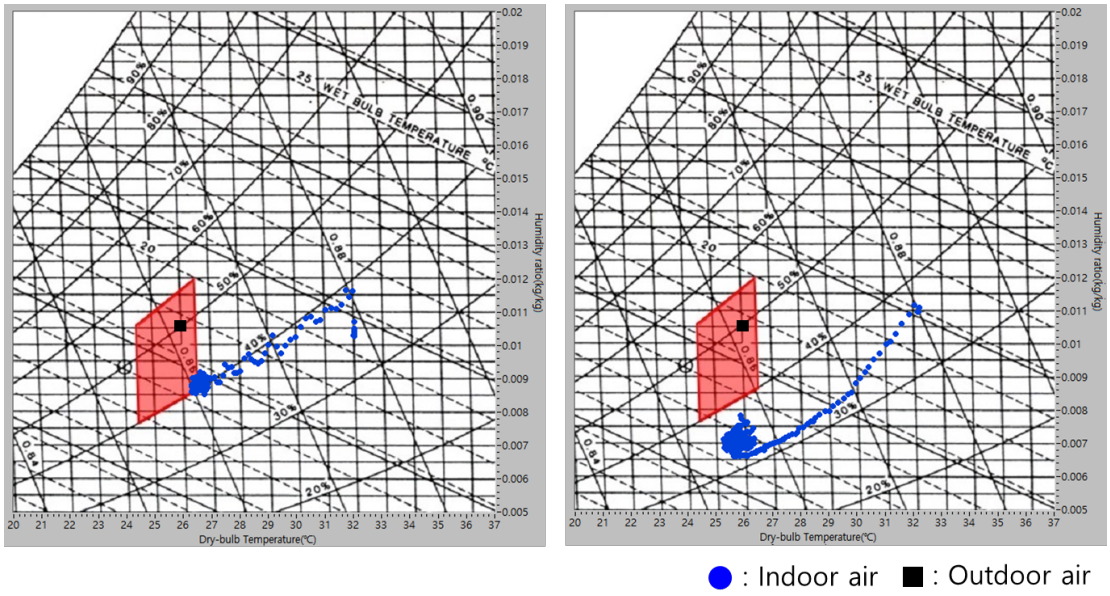


***Figure 4.*** *Indoor air status profile using the Integrated Comfort Control_case1 (Left)*
***Figure 5.*** *Indoor air status profile using the set temperature control_case1 (Right)*

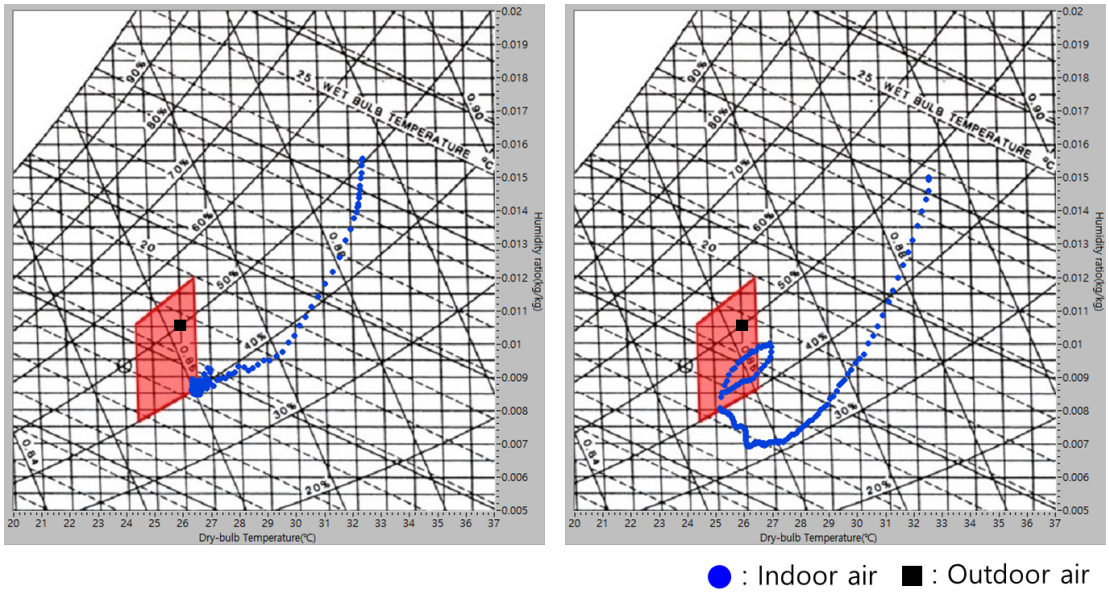


***Figure 6.*** *Indoor air status profile using the Integrated Comfort Control_case2 (Left)*
***Figure 7.*** *Indoor air status profile using the set temperature control_case2 (Right)*

**Case 2**

Figure 6 shows the results for the Integrated Comfort Control. In this situation, the initial condition of the indoor air required cooling, not humidifying. The ventilation time was 10 minutes, and during this time the temperature and relative humidity decreased by 0.2°C and 4%. After using the ventilation system, the VRF system

worked continuously before entering the comfort zone for 36 minutes. The humidifier did not operate when the VRF system started operating. However, the humidifier started operating after 14 minutes because the relative humidity of the indoor air had fallen below 40%. After the indoor air condition arrived at the comfort zone, the VRF and humidifier turned on and off automatically. As shown in Figure 7, the conventional set temperature method expended too much time (131 minutes) to reach the comfort zone, and also could not be maintained within the comfort zone. This suggests that the Integrated Comfort Control method is favorable in terms of the time required to reach the comfort zone and to maintain it.

## DISCUSSION

The result showed that the Integrated Comfort Control algorithm applies well in the testbed as expected in earlier simulation studies. In future research, we will evaluate applications of this algorithm for real office buildings. Also, we are going to examine energy consumptions and the time required to reach the comfort range, and compare Integrated Comfort Control with Comfort Control and set temperature control.

## CONCLUSION

In this study, we performed an experiment to examine how the Integrated Comfort Control algorithm works in the testbed. According to experiments, the ICC algorithm operated the VRF system, a humidifier and a ventilation system differently depending on the conditions of the indoor air. This operating system adjusts to the condition of indoor air to the comfort zone, and also retains temperature and humidity at the comfort zone.

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## REFERENCES

Kim, J.W., 2016. Indoor airflow, An Integrated Comfort Control with Cooling, Ventilation and Humidification Systems for Thermal Comfort and Low Energy Consumption, *M.S. Thesis*, Dankook University (Republic of Korea).

Yang, S.H., 2013. Evaluation of the energy performance and thermal comfort of an air conditioner with temperature and humidity controls in a cooling season, *M.S. Thesis*, Dankook University (Republic of Korea).

ASHRAE. 1989. ANSI/ASHRAE 62-1989, Ventilation for Acceptable Indoor Air Quality. Atlanta: American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc.

ASHRAE. 2004. ANSI/ASHRAE Standard 55-2004, Thermal Environment Conditions for Human Occupancy. Atlanta: American Society of Heating, Refrigeration and Air Conditioning Enginerrs, Inc.

Kum, J.S., Kim, D.G., Choi, K.H., Kim, J.R., Lee K.H., and Choi. H.S., 1998. Experimental study on thermal comfort sensation of Korean. Korean Journal of the Science of Emotion & Sensibility 1(2): 65-73.

Bae, G.N., Lee, C.H., and Lee, C.S., 1995. Evaluation of Korean Thermal Sensation of Office Buildings During the Summer Season. Korean Journal of The Air-Conditioning and Refrigeration 7(2):341-52.