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DEVELOPMENT OF A NEW CO_2-BASED DEMAND-CONTROLLED VENTILATION STRATEGY USING ENERGYPLUS

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Abstract *A significant amount of energy is being used by ventilation and air conditioning systems to maintain the indoor environmental condition in a satisfactory and comfortable level. Many buildings, either new or existing (throughout their renovation process) are subjected to energy efficiency requirements but these must not be in the expenses of indoor environmental conditions. For instance, indoor air quality (IAQ) has to be considered while improving energy efficiency, otherwise occupants might be exposed to inappropriate indoor environment.*

Demand-controlled ventilation (DCV) is a method that provides comfortable IAQ level with lowest energy use. In this paper, the main objective is developing a new CO_2*-based DCV strategy and simulating it using EnergyPlus. The IAQ and energy consumption associated to this strategy have been compared with the results of* CO_2*-based DCV strategies previously developed by the same authors in another article. The comparison shows that the new strategy performs better, both in energy use and IAQ. The recorded energy savings ranged between 6-14% comparing with the previously developed strategies while IAQ slightly improved.*

1. INTRODUCTION

A significant amount of energy is being used by ventilation and air conditioning systems to maintain the indoor environmental condition in a satisfactory and comfortable level. As mentioned in [1], nearly 40% of energy use in buildings are consumed by HVAC systems. Nowadays, both new and existing buildings (throughout their renovation process) are subjected to energy efficiency requirements but these must not be in the expenses of indoor environmental conditions [2]. For instance, indoor air quality (IAQ) has to be wisely considered while improving energy efficiency, otherwise occupants might be exposed to inappropriate indoor environment which might cause health issues. Reviewing many energy-efficient and sustainable ventilation methods, reference [2], noted that integrating control strategies to ventilation systems leads to considerable amount of energy savings. Moreover, it is mentioned that DCV prevents energy waste during low or zero occupancy time because DCV supplies fresh air to and/or extracting stale air from the space only when it is required. For places such as classrooms, auditoriums, offices with variable occupancy level DCV is an appropriate method. Several research studies such as [3], [4], [5] have studied the CO_2-based DCV and stated its noteworthy energy saving potential.

This work comes in the sequence of a previously published article from the same authors [6] in which four occupancy and CO_2-based ventilation control strategies have been defined and simulated to assess the energy consumption and IAQ associated to each strategy. In this paper, a new CO_2-based DCV strategy has been developed and simulated in EnergyPlus in order to compare the results with the results of previously developed CO_2-based DCV strategies. This research has been developed under framework of Smart Window project at the University of Coimbra [7]. One of the tasks of this project is to develop and test DCV strategies for mechanical ventilation. These strategies can be used in spaces where occupants have difficulties in employing natural ventilation. Outdoor pollution and noise, as well as security and privacy purposes are the main reasons to employ solely mechanical ventilation.

2. MATERIAL AND METHOD

2.1. Case study overview

The Indoor Live Lab (I2L) [8], located in Mechanical Engineering Department (DEM) at University of Coimbra, with an area of 46.64 m^2 and 3 meters ceiling height, has been chosen as the test room to conduct simulations. Activity level of 1.2 met, average Du Bois body surface area of 1.8 m^2, infiltration rate of 0.2 h^{-1}, outdoor air flowrate of 24 m^3/h.person and main occupancy schedule, presented in table 1, has been considered for the simulation of all ventilation strategies.

Table 1. Main occupancy schedule

Weekdays Occupancy Schedule									
Time	00-09	09-10	10-13	13-14	14-18	18-19	19-20	20-21	21-24
Occupancy	0	2	5	0	5	3	2	1	0

2.2. Ventilation systems

Constant Air Volume (CAV) fans as well as Variable Air Volume (VAV) fans with different airflow rates have been considered during simulation of ventilation strategies. The fans power is obtained from the following equation: $P = (Q_{fan} \,.\, \Delta p)/\eta$ in which P represents the fan power in [Watts]; Q_{fan} represents the fan airflow rate in [m^3/s]; Δp represents the fan pressure rise in [Pa] (100 Pa is assumed); η represents the fan efficiency (0.7 is assumed).

2.3. Ventilation strategies

Figure 1 presents the new CO_2-based DCV as well as the two previously developed. In the new strategy the VAV fan operates proportional to the CO_2 concentration level and the minimum and maximum setpoints. In the other strategies, in single setpoint, a CAV fan operates only if the CO_2 concentration goes above the setpoint and stops, when it is below the setpoint and in double setpoint, the CAV fan operates when the CO_2 concentration goes above the maximum setpoint and only stops when CO_2 is below the minimum setpoint.

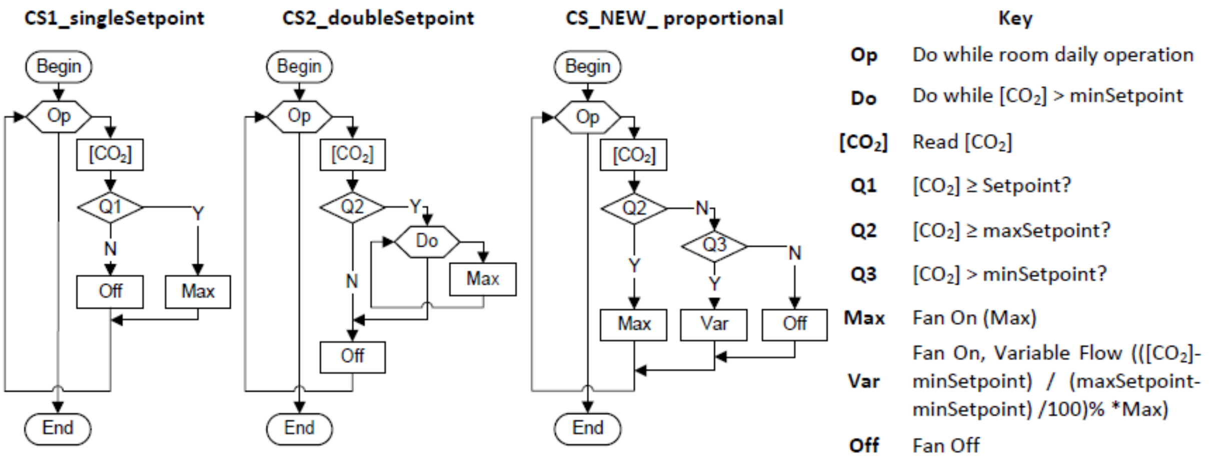

Figure 1. Ventilation strategies flowcharts.

All strategies have been simulated considering the setpoints presented in table 2. To see the influence of different minimum setpoints on the final results, four more strategies have been defined and simulated.

Table 2. CO_2 setpoints [ppm]

Control strategy		CS1	CS2	CS2.1	CS2.2	CS_NEW	CS_NEW1	CS_NEW2
Single setpoint		1000	--	--	--	--	--	--
Double setpoint	Minimum	--	800	900	950	800	900	950
	Maximum	--	1000	1000	1000	1000	1000	1000

3. SIMULATION RESULTS AND DISCUSSION

In this section the results have been presented and discussed. Moreover, comparisons between strategies considering the IAQ and energy consumption have been performed. Considering the base strategies, the CO_2 concentration in the CS_NEW never reaches the maximum setpoint while the other two does (see fig. 2, left part). Based on the monitored data, CS_NEW performed better for both IAQ and energy use. In energy consumption, 6% less than both CS1 and CS2, and in IAQ (average CO_2 concentration in the office), 3% better than CS1 and almost same as CS2 (see fig. 3).

Unnecessary ventilation -over ventilation- can be observed in CO_2 concentration and the fan airflow rate graphs, between 18:00 and 21:00 which causes more energy use. To avoid it, minimum setpoints closer to the maximum setpoint have been defined for CS2 and CS_NEW. From the graphs depicted in the right part of figure 2, it can be seen that the CO_2 concentration levels are slightly higher than the base strategies but still acceptable. The results showed that the fan energy consumption for all strategies is lower than the base strategies and the IAQ is suitable. As shown in figure 4, choosing a minimum setpoint closer to the maximum set point in CS_NEW reduces the energy use while the IAQ drop is negligible. Increasing the energy consumption in CS2.2 comparing with CS2.1 might be due to passing the optimal minimum setpoint for double setpoint strategy, but for the CS_NEW (proportional strategy) it did not happen. In the other word, it can be said that the closer the minimum setpoint to the maximum setpoint the higher the energy saving. Of course the IAQ will decrease but to still satisfactory level for the occupants.

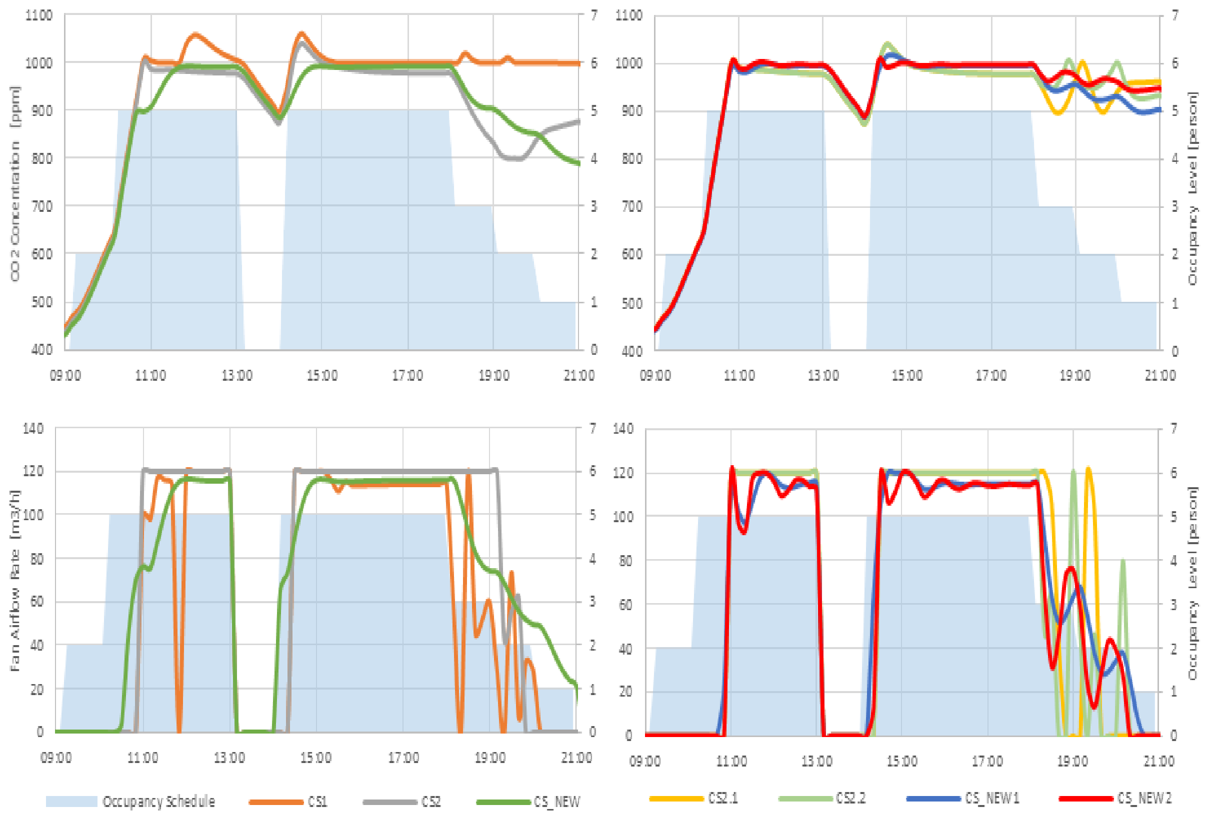

Figure 2. Variation of CO_2 concentration and fan airflow rate in all strategies.

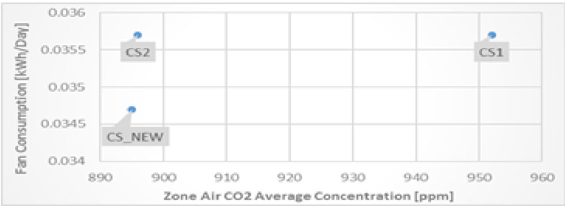

Figure 3. Room average CO_2 Level and fan energy consumption for base ventilation strategies.

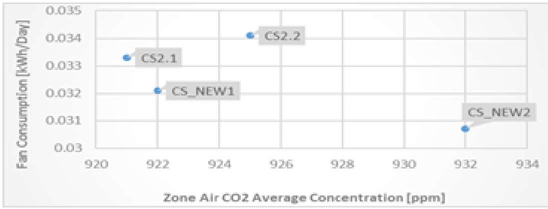

Figure 4. Room average CO_2 Level and fan energy consumption (modified minimum setpoints).

4. CONCLUSIONS

In this paper, a new CO_2-based DCV strategy has been developed and simulated with EnergyPlus. The IAQ and energy consumption associated to this strategy have been compared with the results of CO_2-based DCV strategies previously developed by the same authors. The comparison displayed that the new strategy performs better both in energy use and IAQ. The main findings of the present study can be listed as following:

- Proportional CO_2-based ventilation strategies have higher energy performance than simple strategies.
- In proportional strategies, the closer the minimum setpoint to the maximum setpoint the higher the energy saving.

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