Challenges and Needed remedies of Demand Controlled Ventilation



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Introduction

A recent position paper by the Nordic Ventilation Group (NVG) emphasizes the importance of demand controlled ventilation (DCV) systems in buildings and the necessity of addressing current challenges in these systems. The position paper is available on NVG web page at: https://www.vvsfinland.fi/foreningen/nvg/. It is based on the group´s collective experiences and the results of the Nordic Ventilation Forum on 21st September 2022, and some other relevant references. It applies to all building types with DCV systems with a main focus on commercial and public buildings.

1. Need for DCV systems in buildings and potential advantages

Sufficient ventilation must be ensured in buildings, which in many cases calls for increased airflow rates during times of occupancy. At the same time there is a strong demand for a substantially reduced use of energy, which creates an evident need for DCV systems in buildings [1]. Currently, close to 40% of the total energy consumption in Europe is used for buildings, and a substantial part of that is used by the ventilation system [2,4]. According to scientific studies, the energy consumption of heating, ventilation and air-conditioning (HVAC) systems can be reduced by 20-50% [1-3] with DCV compared to the systems with fixed ventilation airflow rates. This depends strongly for instance on the room usage/occupancy profiles in the buildings, which vary significantly in different spaces. Typical occupancy ratio is for instance 30%-40% in many office buildings [6].

2. Current systems and their principles

The main principle of the DCV system is to maintain good indoor climate conditions for occupants in buildings by dynamic control of the ventilation supply and exhaust airflow rates depending on occupancy, pollution load and thermal load. These systems are called also variable air volume (VAV) systems. Typically, also water-based heating and cooling room systems (for instance chilled beams, fan-coils or radiant panels) are linked to the DCV system. With these systems, the airflow rate is determined with respect to occupancy and excess cooling/heating demand is covered with water-based systems. HVAC systems based on fixed ventilation rates (CAV systems) need to be dimensioned for the most demanding situation which requires the maximum airflow rate and they are not able to reduce the ventilation fan energy consumption and cooling/ heating energy consumption, as opposed to the case with DCV systems.

Typically, in a DCV system, ventilation airflow rates are controlled based on schedule, occupancy detector, temperature sensor and indoor air quality sensors. The most commonly used indoor air quality sensors in DCV systems measure carbon dioxide (CO_2). Control of airflow rates in DCV systems can be designed for individual rooms, zones or specific modules in open areas like landscape offices.

DCV systems in apartment buildings can control ventilation airflow rates at the apartment level. This is typically done by switching to low airflow rate when the apartment is empty or by having a boost airflow mode when the kitchen hood is used. Additional kitchen hood exhaust air should be properly balanced by controlling the supply airflow rate in the DCV system. This should be done carefully when several apartments are boosting at the same time.

For maintaining the desired indoor climate conditions, the DCV system should control ventilation airflow rates at room level. Commonly the target for controlling ventilation airflow rates at room level is also to maintain the balance between supply and exhaust. Three most typical concepts for exhaust air flows are:

- Supply and exhaust airflow rates are balanced at room level.
- Constant room exhaust airflow, and when supply airflow is boosted, the room is over-pressurized, and the boosted fraction of the airflow is transferred from the room to central exhaust.
- Only supply air terminal units are installed in rooms and all the exhaust air is transferred from the room to centralized exhaust.

DCV systems can be defined as pressure-independent and pressure-dependent system categories related to the control of ventilation airflow rates.

- Pressure-independent systems require variable air volume (VAV) control dampers/units at all locations of ventilation ductwork where the ventilation airflow rate is measured and controlled to the desired level.
- Pressure-dependent systems use constant static pressure (CSP) control dampers to adjust each ventilation air ductwork zone to the desired level. CSP dampers include typically the measurement of airflow rate and static pressure at the specific location of the ductwork zone. It can be applied to supply air and the ductwork zone is needed to be designed for maintaining a constant static pressure level by utilizing the static regain principle after room branches.

3. Problems in the performance of current DCV systems

This section presents a summary of identified problems and challenges with DCV systems in buildings based on the Nordic Ventilation Forum presentations and discussions. These were based on experiences from real building cases as identified challenges for DCV system usage [4,5,8]. Technical problems may arise in any part of the processes of design, installation, commissioning, and operation. Any technical problem has a potential to become serious if it is not identified and properly corrected promptly. Obviously, the risk of serious problems increases if there is not a dedicated and adequate quality assurance system in place. Systematic quality assurance is really needed given that DCV systems are complex, they need more knowledge and they include more sensors and actuators than ventilation systems with constant airflow rate systems. As indicated above, problems appeared at all stages of the building process: design, installation, commissioning and operation. Some key findings are listed in the following according to the building process stages:

Design

- Too narrow and asymmetrical ductwork for proper DCV system operation
- Ventilation airflow rate range from minimum to maximum is typically very large (1:8) in commercial and public buildings causing measurement and control challenges for DCV system design and operation
- Level of DCV system documentation was not sufficient or based on general standard schemes
- Too low ventilation airflow rate in rooms due to undersized AHU or duct system caused by incorrect pressure loss calculations
- Noise problem due to system without zone dampers
- Imbalance (pressure difference between rooms) due to supply and exhaust covering different zones, with no air-transfer
- Unstable operation due to too low flow rate over VAV unit (VAV unit cannot measure flow rate)
- Mixing CAV and DCV in the same system, using the same supply air temperature to both system types. Either the CAV-rooms become too cold or the DCV-rooms too warm

Installation

- Actuators and control sensors were installed in the wrong places
- VAV dampers were installed in difficult locations regarding the maintenance
- VAV damper reports wrong air flow rate due to incorrect installation (wrong direction, too close to duct bend/t-branch, not proper safety distances used or found in drawings)
- Some electrical wires were not connected
- Loose, compressed or wrongly installed pressure tube in pressure measurement
- Too small or too high ventilation airflow rate in room due to wrong location of room CO_2 sensor
- Noise problem due to VAV-unit located too close to duct t-branch

Commissioning

- In the control of minimum-medium-maximum ventilation airflow rates in the room, the medium-maximum airflow rates were in the wrong order
- The ratio of supply and exhaust ventilation airflow rate was not correct
- The setpoint for the room air temperature was too low, leading to continuous unnecessary cooling with the maximum airflow rate
- Wrong k-factor for VAV flow-cross in VAV unit program parameters
- Too small ventilation airflow rate in room due to too low pressure setpoint in the duct
- Too small or too high ventilation airflow rate in room due to incorrect programming of the VAV unit
- Connections to building management system not correctly and clearly done

Operation

- Building management personnel did not know how to use automation systems and did not understand the overall operation

- HVAC and automation design documentation was not available in many cases
- VAV-pressure transducer blocked with dust or broken
- Exhaust airflow measurement devices were dirty and gave the wrong airflow rate leading to imbalance (pressure difference between rooms) or unstable operation of the system
- Noise problem in pressure-controlled systems due to pressure sensor damaged due to pressure or electrical spike
- Imbalance (pressure difference between rooms) due to zero pressure error in pressure transducer due to pressure/electrical spike
- Mechanical fault with VAV damper blade operation
- Too high supply air temperature due to lacking thermal insulation of supply air ducts installed in warm spaces (e.g. attics during summertime)
- Too high supply air temperature leading to open VAV dampers without adequate cooling power

4. What is needed and should be improved for reliable and well-performing DCV systems

Based on the Nordic Ventilation Forum presentations and discussions, the following improvements related to the design, installation and operation of DCV systems are suggested.

- Training of designers, contractors, and maintenance staff should be improved
- Proper design should focus on requirements that can be verified
- Documentation should be up-to-date and property/system-specific
- Commissioning tests before the building is occupied should include tests of all operating modes of the DCV system
- Commission and maintenance processes/contracts should be improved
- BMS for continuous monitoring should be utilized and need to be well-designed
- Maintenance staff appreciation and motivation should be improved
- Inspections and retro-commissioning should be performed regularly

Needed improvements related to the technology of DCV systems:

- Large and reliable measurement range of airflow rates in VAV measurement units
- Smart and robust control systems
- Utilization of IoT to monitor indoor climate conditions and systems operation

These reported improvements are suggested to be implemented with more detailed specifications for achieving reliable and well performing DCV systems in buildings with good indoor climate conditions and efficient use of energy during the entire building life cycle. ■

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