WS 11 – Demand Controlled Ventilation

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INTRODUCTION & BACKGROUND
With an unrelenting drive to find ways to reduce energy consumption in our building stock, ventilation solutions are necessary to maintain a healthy comfortable indoor environment. Naturally, tailoring systems to deliver only what is needed and no more or less; Demand Controlled Ventilation (DCV) is an area of interest. The workshop took a critical look at the state of DCV system technology available today and the impact of regulation and code. The workshop focused on topics about: the appropriate proxy and indoor climate, energy and economical evaluations, design and optimisation of DCV systems, sensor technology and placement, commissioning, operation and maintenance competence.

SUMMARY OF THE PRESENTATION

1. ***DCV Definition and limitations***

For the purpose of the discussion the Demand Controlled Ventilation (DCV) system was defined as a ventilation system with feed-back and/or feed-forward control of the airflow rate according to a measured demand indicator. The airflow rate may be controlled by the measured state of air (feed-back control), the measured load (feed-forward or predictive control) or a combination of these [1]. Demand is decided by a set of values affecting thermal comfort and/or air quality. The main indicator for thermal comfort is room temperature or sometimes a combination of temperature and humidity (specific enthalpy). The main indicator for air quality is the composition of air in terms of gases and particles. The ventilation flow rate needed to guarantee the required air quality is known as the hygienic flow rate.

2. ***Energy performance and feasibility***

Demand Controlled Ventilation systems have become commonly applied as energy efficient alternative to Constant Air Volume (CAV) systems not just in the new buildings but also in the refurbishment projects. In order to evaluate the potential of DCV systems and their feasibility in different applications it is important to know what really determines the energy performance of such systems and how to correctly estimate the energy savings in the feasibility analysis.

By adapting the flow rates to the actual demand the average airflow rates will be decreased and less energy is needed for fan operation and for heating and cooling of the supply air. Energy use is dependent on a number of factors such as required minimum fresh airflow rates, demand variation, system design, control strategies, etc., and therefore the energy saving potential and feasibility of each application need to be assessed individually.

Demand variability is one of the main decisive factors for DCV system energy use. DCV systems are most suitable for premises with varying load conditions and high density occupancy. The more the loads are varying in time, the more energy savings can be expected with a DCV system compared to a conventional CAV system.

There are very few calculation guidelines available on how to correctly estimate the fan power at varying airflow rates in a DCV system [2, 3].The fan energy performance is dependent on pressure and flow control strategy in the system as well as on the fan characteristics and more research is needed in this field.

3. *Proxy and indoor climate*

DCV systems based on indoor air quality control aims to adapt the airflow rates to the varying pollutant emissions in the room, e.g. from occupancy, activities, varying processes. There are no sensors that measure the "quality" of air. Instead, quantitative parameters, as the composition of air in terms of gases and particles, can be measured and linked to the air quality. What is the best indicator for controlling the emissions generated by people and their activities is still an important question with no clear answer. Carbon Dioxide is commonly used as a proxy in premises with varying occupancy. The discussion is still on-going if carbon dioxide control of ventilation airflow rates leads to good indoor air quality and assures required airflow rates or if there is any other proxy which is better.

4. *DCV System technology*

During the last ten years the DCV technology has developed considerably, especially regarding the DCV air supply devices and system control technology. However, in order to have the expected performance a holistic approach from the very beginning of a design process is needed. It is important to analyse the technical aspects of a DCV system and the requirements to be set on its components on a room, zone and system level (illustrated on Figure 1).

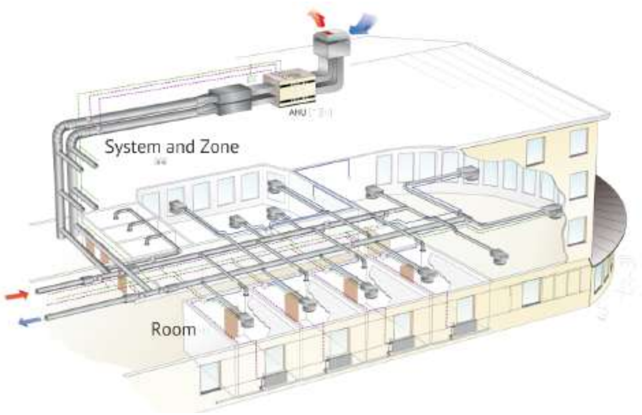
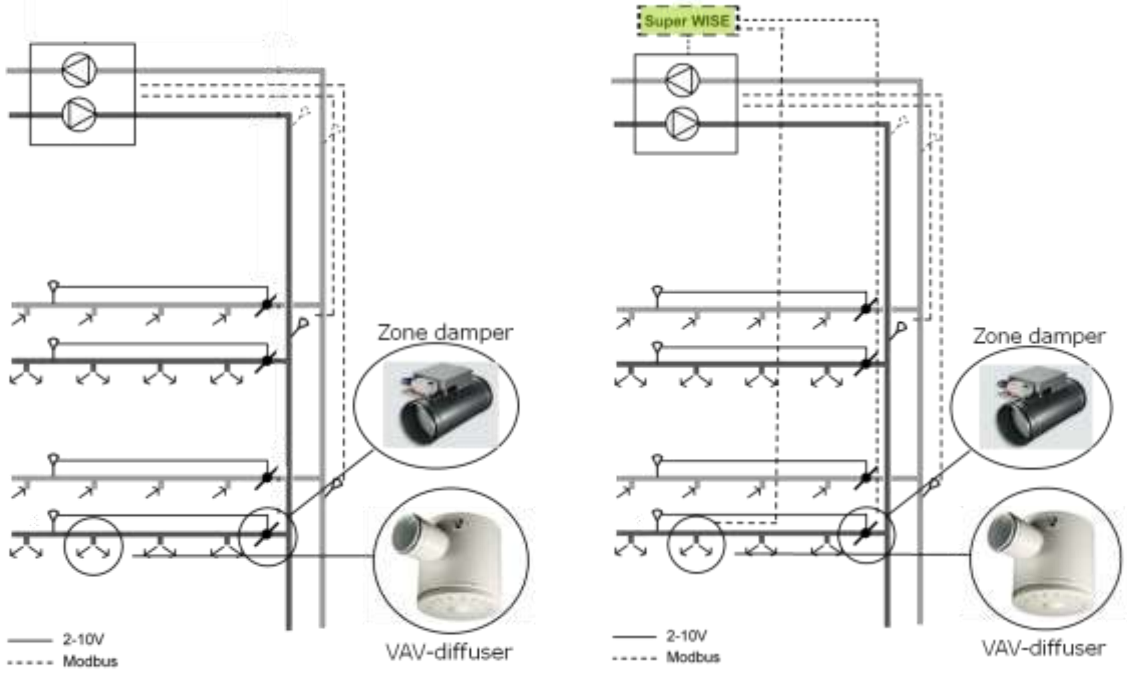


Figure 1: DCV System technology – zone and system level along with room levels

There are two common ways to vary the airflow rates on a room level. The airflow rate in individual rooms is adapted to the demand either by airflow control dampers (VAV-dampers) in the duct connecting the room or by variable supply air diffusers (VAV-diffusers) in the room, which are designed to keep the air speed of the flow pattern within limits at varying airflow rates. The sensors commonly applied in DCV systems are temperature sensors, humidity sensors, occupancy sensors and gas sensors, e.g. CO_2 sensors, VOC sensors.

One very important aspect that characterises a DCV system is that varying airflow rates on room levels lead to varying static pressure in the system. Pressure control methods have been commonly applied to avoid unnecessary throttling at the airflow control devices when the average airflow rate is low. Previously a common approach has been to keep a constant static pressure in the system, right after the air handling unit or at a chosen location on the main duct brunch. Control technology development has introduced new possibilities to optimise the fan performance and energy use of the DCV system. For example optimising static pressure set point based on VAV-device or zone-damper device openings or calculating the needed airflow rate from central air handling unit based on the measured flows at VAV-diffusers and dampers and adjusting the flow at the zone and air handling unit (see Figure 2).



Constant static pressure control

Optimized pressure set-point/ volume flow control

Figure 2: Pressure control and air flow control schematics

A DCV system puts also a higher demand on the fan design and its performance. The fan is expected to operate in a stable manner over a wider airflow range compared with a CAV system. This must be considered to avoid problems with noise, controlling the airflow rates accurately. Additionally, the efficiency of the fan falls rapidly when the airflow rate gets below the 20-40 %. The modern fan technology for example brushless DC motors (BLDC) have the efficiency decrease at very low airflow rates compared to conventional AC induction motors. This also points out the fact that over dimensioning of the fan system in a DCV system should be avoided [3].

5. Maintenance and operations

The commissioning of DCV is a process defined by each manufacturer. When the different components of the system come from the same manufacturer, the commissioning work as well responsibilities are much easier to be defined and executed. During the lifetime of a DCV system it is commonly the sensors, motors/dampers that may require more frequent inspection. These procedures need to be written to the system maintenance manuals.

6. Competence and know-how

In order to guarantee adequate performance of a DCV system and to achieve the expected energy savings, it must be designed, installed, commissioned and operated under a constant and complete process in order to fulfil the needs of end-user and investor.

DISCUSSION AND MAIN RESULTS

Energy performance and feasibility

Based on the discussion on where DCV systems have had the best impact; schools, auditoriums, seminar rooms, theatres, cinemas and office buildings were pointed out. Also commercial kitchens were discussed as being a good application area, due to varying load of appliances used in these premises. Based on the received feedback, the current practice of automatic variation of airflow rates based on the actual demand has been quite often just on single room basis, i.e. demand controlled airflow rates only in a limited number of rooms in the building, for example meeting rooms or auditoriums. The number of references with complete DCV solutions in the building seems to be still rather limited.

There is also a need for more detailed information on how to evaluate demand variability in buildings in addition to what simultaneous factors should be used when dimensioning the system components, e.g. air handling units, duct system and future flexibility in building use.

When estimating the energy performance of the fan system in a DCV system ASHRAE polynomial equation is used [2]. The same equation also seems to be incorporated into building simulation tools. More long-term monitoring of DCV systems energy performance is needed to validate the existing calculation methods with the current DCV system technologies.

Proxy and indoor climate

The CLIMA 2010 DCV workshop discussed whether CO_2 was always the best proxy for reflecting IAQ in non-residential buildings. However, the discussion on what other proxy to be used for IAQ has made no significant progress. No relevant research outputs were brought up during this workshop discussion. However, the importance of analysing the activities in the room, degree of tolerance (number of dissatisfied people) and the level of indoor air quality required for a specified activity were pointed out to be highly relevant when determining the suitable proxy. VOC-sensors for IAQ control was discussed since the VOC-sensors are less expensive than CO_2-sensors due to the recent automotive developments. Calibration and interpreting the output signals from VOC-sensors is still rather incomplete.

The importance of proper placement of CO_2-sensors was highlighted in the discussions. When choosing the location for the controlling sensor it is important to take into account that stratification of CO_2 between the different levels in the room may occur. The stratification is dependent on the air change rates and how effectively the air mixes in the room [4].

DCV systems technology

There are different kinds of airflow control devices available on the market nowadays. With some of the devices problems with measuring low airflow rates can occur, but there are also products where low airflow rates can be measured with good accuracy. According to the discussion the biggest area for improvement within DCV systems is to evaluate the airflow rates correctly and effectively adapted to the actual occupancy in cost effective ways.

Additionally there is a need for good and simple interfaces between ventilation and heating/cooling control strategies. Combining heating and cooling with DCV system has shown in one office building in Sweden that duct heat losses need to be taken into account when the system operates with low airflow rates and low air speed. Previous research has shown that in a DCV system, adding insulation to the main ducts gives bigger effect in terms of decreasing heat losses or heat gains in the case of heating or cooling with air, compared to when adding insulation to the connection ducts on the room level [1].

The current DCV control technology for overall system performance optimisation, e.g. for system pressure set point optimisation or direct flow control on an air handling unit level, seems to also perform well. The experience on building up control systems for pressure set point optimisation has shown positive results.

__Maintenance and operations__

Discussions on experience with maintenance and operation of DCV systems revealed that in some countries it is not always easy to convince the client to invest in proper commissioning and maintenance of DCV systems, resulting in problems with the DCV systems' operation. This is very important for achieving good indoor climate and energy performance of the building during its lifetime. A detailed research study is needed for demonstrating to the investors the importance and value of proper commissioning and maintenance in operation. The client/investor needs to set clear responsibilities and demands for DCV systems commissioning, functional performance checks as well as for system operation and maintenance.

Practical experience has shown that successful results can be achieved when the client is both the builder as well as the building owner/manager during first years of building operation, making sure that the building and its systems operate well before selling the building or handing over the building to another entity. It was also discussed that in the UK, there is a process implemented, called "Soft Landings", which means that designers and constructors are staying involved with buildings beyond practical completion date. The aim is to assist the client during the first months of operation and beyond, to help fine-tune the systems, and ensure the building users understand how to control and best use their buildings.

In the discussion on long-term experiences with DCV systems it was pointed out that it is the knowledge of the whole system function, proper commissioning work, maintenance and operation that are key elements for the good performance of the systems. The DCV system technology development has been very fast during the last decade. It is important to make sure that the systems installed in the buildings work, otherwise it would be just too costly to replace them. Also, the legislation should support the obligation of having systems properly commissioned and set the demands for companies for carrying out functional performance checks during first years of operation, i.e. legislative tools for forcing the follow up are needed.

__Competence and know-how__

Building up a well-functioning DCV system involves a number of different stake holders and key actors from the very beginning of the planning process until to the final system operation. It is the client/building owner who sets the preliminary requirements for the building and its performance at the very beginning of the planning and design process. The designers need to have a proper knowledge about how the planned DCV system functions and should be operated, prepare the necessary documentation and drawings to the contractors and client/owner for them to understand how the system was being built, commissioned and operated. The client/building owner should also hand over proper documentation of the systems and their operation to the end users for them to be able to understand the systems and properly manage them.

When sharing the current practices in the group discussion, quality issues in the installation processes were pointed out, where in number of cases the installers have cut the costs during installations and jeopardised the quality of the results. Legislative tools could be needed for helping to clarify the roles and responsibilities of different key actors involved in the process of building up well-functioning systems as well as assuring their good performance to the very end of the building life. To conclude, a holistic approach should be applied in the process of assuring well-functioning systems.
When products from different manufacturers are installed in the DCV system then it is very important that these products are able to interact with each other through a common protocol.

CONCLUSION AND FUTURE WORK DIRECTIONS IN THE FIELD

Future research

- Evaluation of demand variability in DCV applications and specifying guidelines on how to evaluate the demand variability in the design process.
- Further studies on whether CO_2 is the best proxy to be used for control of air quality in non-residential buildings and what other proxies can be relevant in different applications.
- Long-term monitoring of DCV systems energy performance for developing detailed guidelines for energy use calculations, taking into account different control strategies and performance characteristics of the system components, e.g. fans, heat exchangers, heating and cooling coils, ducts system, controlling dampers.
- Studies on how to assure DCV system flexibility in the design process in order to take into account possible changes in demand in the future.
- Developing good standard based control strategies and interfaces for assuring good performance between DCV system and other technical systems, e.g. heating and water-based cooling.
- Studies on demonstrating the economic aspects of building up a well-functioning DCV system, including the importance of proper installation, commissioning and operation.

Development and implementation of legislation

- Legislative tools for helping to clarify the roles and responsibilities of different key actors involved in the process of building up well-functioning systems and assuring their good performance until to the end of the building lifetime.
- Legislative tools supporting the obligation of having DCV systems properly commissioned and setting the demands for companies for carrying out functional performance checks during first years of operation, i.e. legislative tools for forcing the follow up are needed.

Application of best practise

- Clear and understandable visualisation of outputs from controls for the occupants to show the action/reaction process in controlling of a building.
- Passing over a proper project and building documentation to all entities involved in the life of a building (designer, contractor, investor/owner, maintenance).
- After 2 years the building’s energy and IAQ performance is checked against the specification designed to.

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