VAV system with genuinely demand-controlled fans

"Ventilation systems that deliver increased comfort while consume less energy"
– wishful thinking or reality?

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This article explains the disadvantages of duct pressure control in variable-volume ventilation systems and shows how they can be replaced with forward-looking, demand-controlled systems that comply with EN 15232, Class A*.

Demand-controlled ventilation (DCV) - benefits

Much has already been written about the benefits and possibilities of DCV systems. This technology measures the conditions in the room and calculates the amount of energy actually required. To do this, it uses sensors and control devices for CO_2, VOC, temperature, light and so on. The required volume of air is supplied to the room by precise volumetric flow controllers - a technology known as variable air volume (VAV).

If we look at the average consumption of typical room zones **Figure 1**, we can see that these are mostly operated at part load. The best efficiency point, the maximum flow rate, is only rarely needed.

Fan control

Efficient fan control is a vital part of a DCV system. To regulate fan output, frequency converter-controlled fans are increasingly being joined by EC fans. To adapt the fan power made available to the ventilation system, the DCV system must gauge the ventilation system's requirements and set a suitable set point. This is the weak point of traditional duct pressure control systems

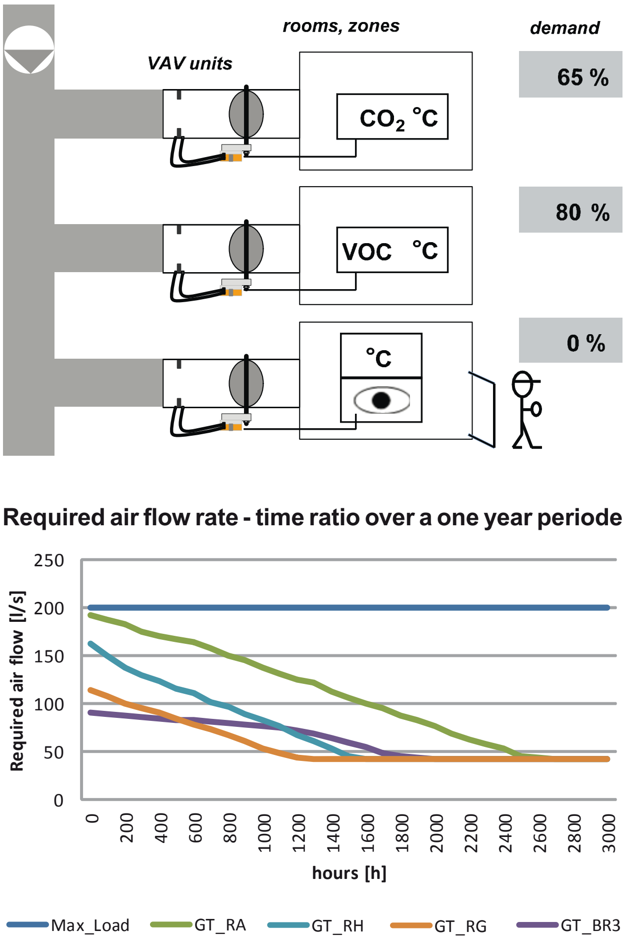

Figure 1. Most of the time the room units DCV system are working at part load.

* Energy efficiency class A in EN 15232 (Energy performance of buildings) stands for highly energy-efficient building automation and technical building management..

Figure 2 and the strength of the pressure feedback Fan Optimiser system **Figure 3**.

Duct pressure control

The setpoint *K* for duct pressure control **Figure 2.** corresponds to duct pressure *P1*, the pressure required to move the maximum air volume *V1* through the air duct system. The actual pressure is measured in the air duct, ideally at the most unsuitable point in the ductwork. Question: Where is the most unsuitable point in a variable-volume ventilation system? The answer is that it moves around the duct system according to the ventilation system's current load distribution. So it is only possible for the pressure sensor to be incorrectly positioned; it is usually installed immediately downstream of the fan.

The main drawback of this method is that the fan is controlled on an open loop basis. The volumetric flow V2 required at any given moment, is not used to calculate the set point as there is no feedback from the volumetric flow controllers available. The duct pressure and VAV boxes are operated independently of each other. If the volumetric flow is reduced from *V1* to *V2*, the pressure in the air duct system rises in line with the fan's characteristic curve. The pressure control system then brings the duct pressure back down to point *K*, the full load level; the correct, reduced set point *R* is unknown. The downstream VAV boxes are forced to eliminate the surplus duct pressure *P1-P2* by throttling the dampers. In practice, systems of this type sometimes contain VAV dampers throttled by up to 10% – see damper diagram **Figure 4**.

The result: excessive noise and unnecessarily high pressure losses in the air duct system, leading to excessive energy consumption by the fans.

Another disadvantage of pressure control is that every change in use and every adjustment to volumetric flow

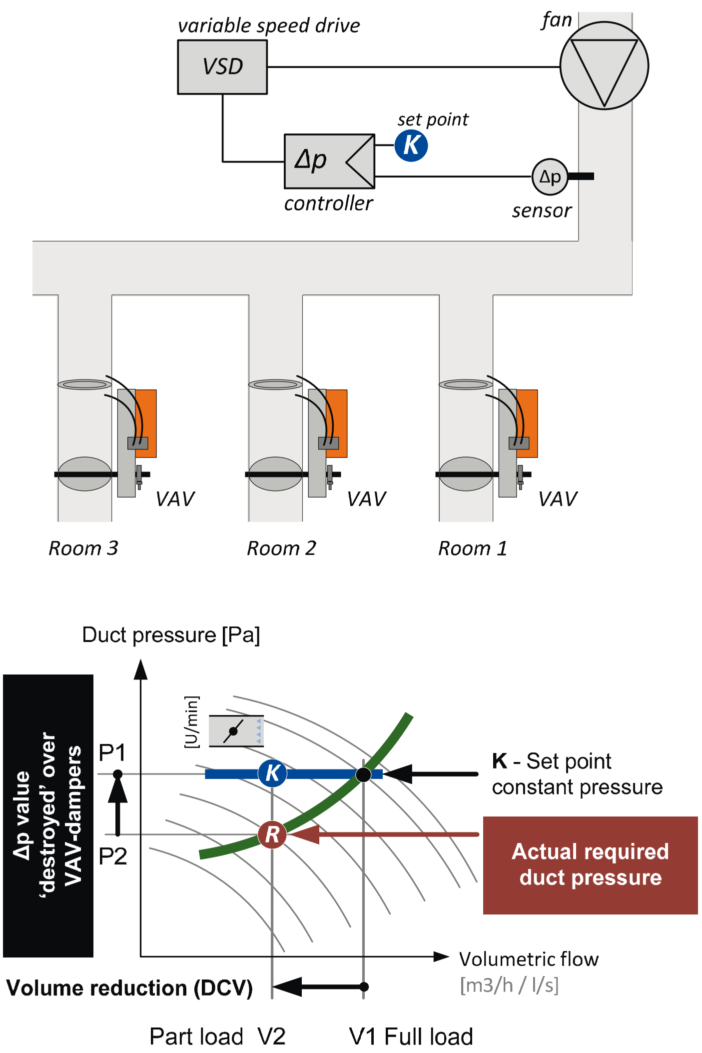

Figure 2. Duct pressure controlled VAV system: Open loop control.

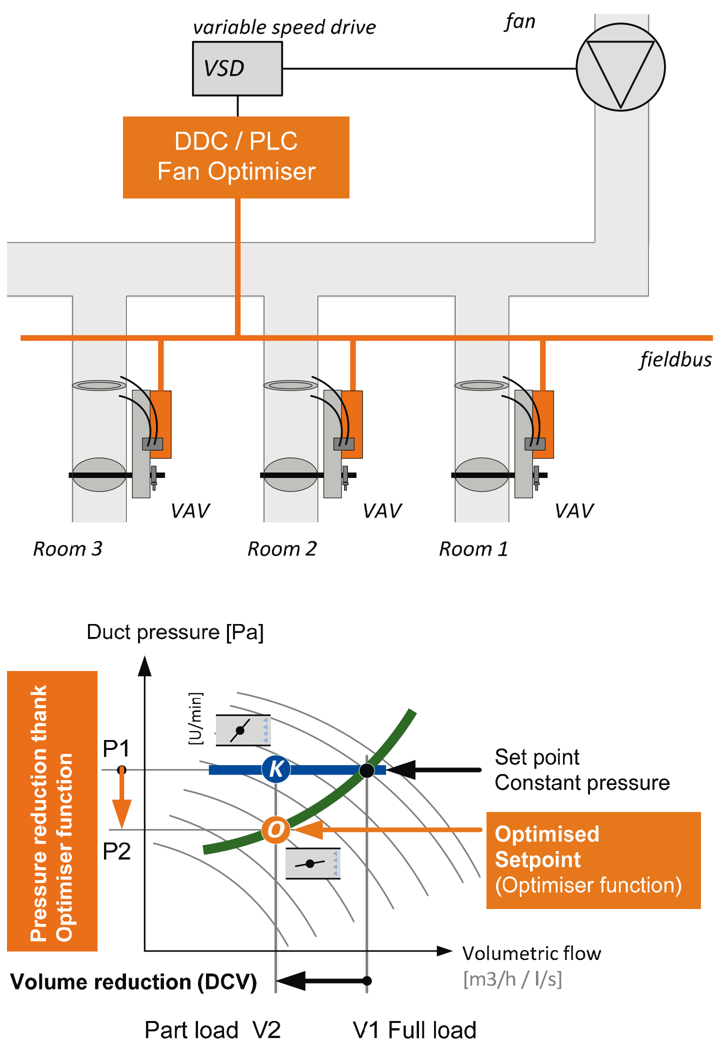

Figure 3. Pressure feedback, Fan Optimiser-controlled VAV system: Closed loop control.

requires a manual correction of the *duct pressure set point* parameter, which in practice usually does not happen – and this has consequences too.

Fan Optimiser – the pressure feedback volumetric flow control system

In a pressure feedback volumetric flow control system **Figure 3** the damper positions of the VAV-Compact controllers are gathered via a field bus (MP-Bus, LONWORKS®, Modbus, KNX etc.) and used as the trigger for energy-efficient control of the fans. The damper positions are evaluated by the Fan Optimiser function and the fans are brought down to the optimum set point *O* until most of the dampers are in the optimum operating range **Figure 4**.

Dampers close - falling demand / pressure too high, dampers open - rising demand/pressure too low: the fan is powered up or down accordingly following the ventilation system's characteristic curve (optimised set point *O*).

The result: less noise and reduced pressure losses in the air duct system, leading to considerably reduced energy consumption by the fans.

Damper diagram

The efficiency of both methods can be seen in the damper diagram **Figure 4**.

In the Fan Optimiser system, the lowered duct pressure *P2* takes strain off the system and helps to extend the lifetime of the actuators through the reduced number of part-cycles.

Further advantages:

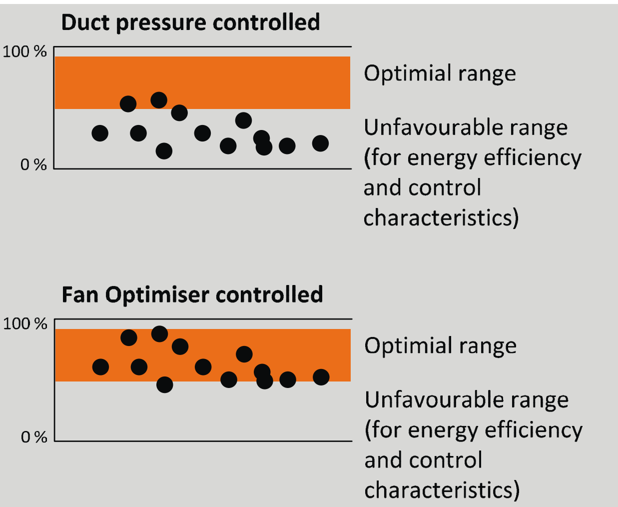

Figure 4. Damper positions: Duct pressure controlled versus Fan Optimiser controlled.

- A Fan Optimiser system automatically finds the required operating point at any given time, so there is no need for time-consuming balancing work of the duct pressure system.
- With Fan Optimiser technology, duct pressure controlled systems require no reserve Δp additions (such as compensation for filter contamination etc.).
- Changed system configurations due to a change of use etc. are detected automatically by the Fan Optimiser and taken into account in operation.
- Undersized systems will work as long as the required set volume *O* is less than the available volumetric flow. This is not generally the case with duct pressure controlled systems.

System design

Pressure feedback Fan Optimiser systems **Figure 3** can be designed in two ways:

a) DDC / programmable controllers: Bus master devices with custom-programmed Fan Optimiser application

b) Fan Optimiser hardware: Device with preconfigured, ready-to-use Fan Optimiser function, e.g. COU24-A-MP

In both variants the VAV-Compact controllers are integrated into the control system with a field bus (MP-Bus, LONWORKS®, Modbus, KNX etc.) and the Fan Optimiser function uses the damper positions to calculate the set point for the air supply.

If the system is configured as a bus system, or if a bus system is already installed, there are essentially no additional hardware costs. The duct pressure control equipment and laborious sensor positioning are not required for solutions a) and b).

Potential savings - Case study

The volumetric flow and its transport are determining factors for the energy consumption of the fans. The rules of proportionality form the foundation:

- Rule 2 describes the pressure reduction P1► P2: The pressure increase changes as the square of the volumetric flow ratio.
- Rule 3 describes the volume reduction V1► V2: The power consumption changes with the volumetric flow ratio.

Table 1 shows the result of a comparative measurement in an office building. A system integrator programmed the Fan Optimiser function into a DDC controller. The installed VAV-Compact controllers are connected to the

Table 1. Case study in office building: Duct pressure controlled versus Fan Optimiser system.

Control type	Fan	Duct pressure @ last VAV	VAV unit damper position	Var. speed drive frequency	Fan current	Consumption
- Duct pressure controlled	Supply fan	295 Pa	31…39 %	30.6 Hz	9.30 A	2,60 kWh
	Exhaust fan	250 Pa	21…43 %	28.7 Hz	9.21 A	2,47 kWh
					Fan Σ	**5,07 kWh**
- Fan Optimiser system	Supply fan	45 Pa	50…90 %	20.6 Hz	6.70 A	1,07 kWh
	Exhaust fan	20 Pa	47…90 %	18.6 Hz	5.87 A	0,77 kWh
					Fan Σ	**1,84 kWh**
Savings @ actual part load condition (!)						**-3,23 kWh (–64%)**

DDC controller by the integrated MP-Bus interface **Figure 3**. In addition to the Fan Optimiser function, the system also has conventional duct pressure control for taking comparative measurements. Either control function can be selected in order to compare the two strategies under identical operating conditions.

The measured difference on the chosen day was an impressive 64% saving. This result applies only to the specific time and conditions in place on the date in question (occupancy, refrigeration load etc.) Over the course of a year the savings would probably amount to between 20% and 50%, depending on the system and the part-load conditions (weather, internal loads, occupancy and so on).

If we calculate the savings over a year, for instance in a hospital or an apartment block with 24-hour operation 365 days a year, it is clear than the investment pays for itself very quickly. This is especially true in a planned or existing bus system which already has the necessary infrastructure.

Field of application

- Variable-volume ventilation systems for hospitals, offices, hotels, administrative and industrial buildings, etc.
- Variable-volume systems for controlled apartment ventilation. Fan Optimiser systems have already been used successfully in many such applications.

Benefits of a Fan Optimiser system

- Designed for the future – *EN 15232, Class A* compliant solution
- Open system – all CAV/VAV control functions are possible with CO_2, VOC, temperature, presence sensors etc.
- High level of comfort – no reduction in comfort or control quality
- Error compensation – compensates for some design errors
- No reserves necessary – thanks to automatic compensation (filter contamination etc.)
- Easy commissioning – the Fan Optimiser finds its own operating point
- Closed loop – integrated system from room demand to air supply
- Energy-optimised – reduced pressure loss in duct system
- Reduced noise – thanks to lower duct pressure
- Change of use possible – no adjustments required as long as total volume of air is sufficient
- Longer actuator lifetime – thanks to reduced duct pressure
- Short payback time – thanks to low fan operating costs
- Environmentally friendly – reduced energy consumption and CO_2

Conclusion

DCV systems are good news for zone-by-zone demand-controlled energy supply. To operate the whole variable-volume ventilation system efficiently, the fans also need to be fully integrated in the DCV system. The complete integrated system solution for this is the pressure feedback Fan Optimiser. From room level to air supply, it works on the principle of *only as much as necessary – not as much as possible!* ■