CLIMA 2016 - proceedings of the 12th REHVA World Congress

volume 8

Heiselberg, Per Kvols

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Heiselberg, P. K. (Ed.) (2016). *CLIMA 2016 - proceedings of the 12th REHVA World Congress: volume 8*. Department of Civil Engineering, Aalborg University.

Demand Based Controls Approach from the Building Automation System Leads to Very Energy Efficient Fan Operation in a Newly Constructed Office Building

Chris Kopp[#1], Petar Mihaylov[*2], Tore André Haugen[*3]

[#] *Siemens Building Technologies*
Gubelstrasse 22, CH-6301 Zug, Switzerland
[1] chris.kopp@siemens.com
[*] *Bautec AS, Kanalveien 55A, 5068 Bergen, Norway*
[2] petar.mihaylov@bautec.no
[3] tore.haugen@bautec.no

Abstract
The study clearly shows that by utilizing a "demand based" controls approach and the communication means provided by a today's Building Automation System it is easily possible to operate the Air Handling Units – especially their fans – in this office building in a very energy efficient way. This integrated approach reduces the fan power consumption substantially compared to traditional controls approaches and also compared to the operating values thought necessary during the design phase. The study compares theoretical fan power consumptions with measured data for a recently constructed office building. This comparison shows that power consumption reductions in the range of the theoretical values can be achieved in reality provided that an appropriate ventilation system setup and state-of-the-art building automation components and functions are being utilized. Furthermore it becomes clear that only minimal additional effort by the building automation specialist is necessary to realize such a highly energy efficient solution.
In conclusion this paper underlines that it is easily possible to achieve substantial power consumption reductions through energy efficiency functions provided by a today's building automation system. The paper also shows, that such a "demand based" controls approach goes beyond the energy performance classification as defined in the EN15232 [1] and surpasses the energy savings of its "A-class" definition for flow control in a ventilation system by far.

Keywords – demand based controls; energy efficiency; fan optimization; fan power consumption

1. Introduction

The study was conducted in a newly constructed office building in Norway. The building is equipped with six Air Handling Units (AHUs) that serve Variable Air Volume (VAV) systems for the various office and meeting rooms.

Fig. 1 Office building in Norway with state-of-the-art fan optimization control for the various office and meeting rooms (Source: Bautec AS, Norway)

The building and the HVAC systems are equipped with a state-of-the-art building automation and controls system (BACS). It fully integrates the Room Automation controllers (for heating, cooling, ventilation and lighting), the Room Operating units and the VAV Compact controllers using standard communication means such as BACnet, KNX, Modbus and DALI for lighting.

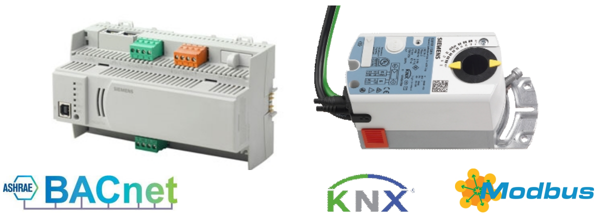


Fig. 2 Typical Room Automation Controller and VAV compact controller integrated into BACS via standard communication (e.g. BACnet, KNX, Modbus…)

Fig. 4 and Fig. 5 show the system setups for the supply air static pressure control of a VAV system. The return air static pressure control is done the same way. These setups utilize the following fan control strategies:

- Constant Δp supply/return air pressure control (Fig. 1; still widely used in existing and even new buildings).
- Demand based Δp supply/return air pressure control (Fig. 2), optimized for maximum possible VAV damper position.

Both control approaches are “A-class” functions accordingly to 4.2 of the EN15232 [1]. The “Demand based Δp supply air pressure control” however by far surpasses the determining conditions for an “A-class” function and the related energy savings potentials stated in the standard.

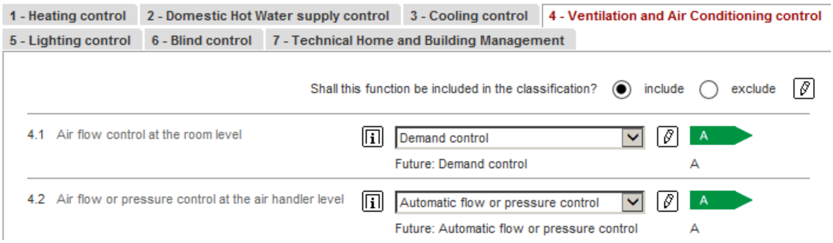


Fig. 3 Definition of “Air flow control” at the room and air handler level according to EN15232 (Source: Screenshot from Energy Performance Classification Tool)

The demand based supply air pressure control utilizes the possibilities of a fully integrated BACS and the capabilities of proven software functions of the BACS for that purpose.

The paper first shows the theoretical energy savings potentials for the AHU fans comparing a design data situation with an actual operating situation at an average air flow rate of 50%.

In a second step trended data from typical operating periods of the building are shown to emphasize that the theoretical energy savings are achievable in real plants by utilizing the BACS and its functionality adding up to substantial reductions of electrical power consumption.

2. Fan Power Consumption Substantially Reduced due to Demand Based Control

For this part of the discussion, we assume for the VAV systems an average air flow rate at 50% of the design flow rate throughout the year. This because the design flow rate ist based on the maximum cooling demand of the rooms, which only occurs occasionally. Most often the actual cooling demand is much lower and the VAV systems are mainly operating to provide adequate air quality in the rooms.

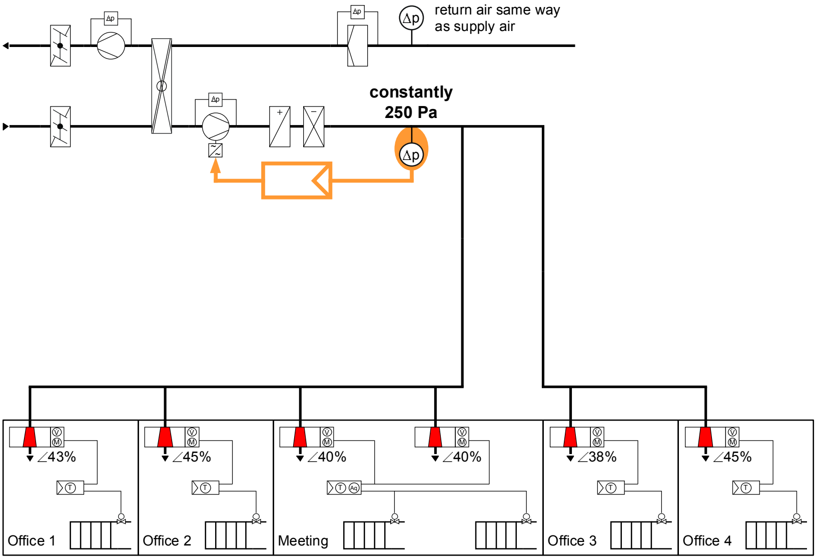


Fig. 4 VAV-system with “Constant Supply air pressure control” – VAV dampers “knock off” excessive duct pressure by massively closing off

Fig. 4 shows the setup of a typical (traditional) „Constant supply air pressure control“. With this control approach the static pressure provided to the VAV-system is maintained at a constant level which very often gets defined during the design phase of the system. The link between the VAV boxes in the rooms and the AHU is achieved via the ductwork because the static pressure control at the AHU reacts to changes created by the moving VAV dampers in the various rooms. In order to ensure that the rooms are supplied with the required amount of air all the time, the level of the supply air static pressure is often set rather high (here at 250 Pa). Because of this, the VAV dampers quite often close heavily (e.g. most are at 40% or less open) to maintain the required air flow to the rooms. By that they basically „knock off“ the excessive duct pressure created by the fan, whilst the fan draws an unnecessary high amount of electrical power.

Fig. 6 illustrates this (based on the fan affinity laws) showing the static pressure across the fan for this control approach at 313 Pa and the corresponding power consumption of the fan at 0.94 kW. It also shows, that doing static pressure control for the supply air is basically an interesting approach, because the power consumption gets substantially reduced at part load conditions compared to the consumption of 3.1 kW at maximum air flow.

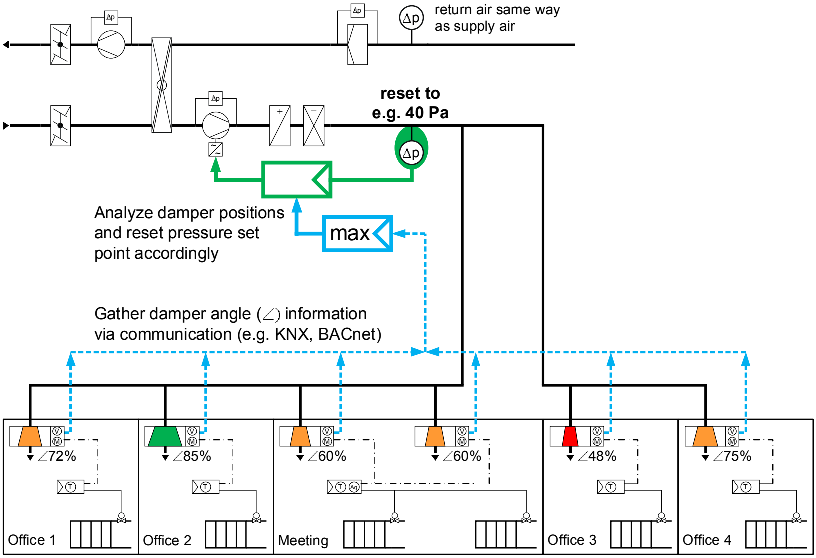
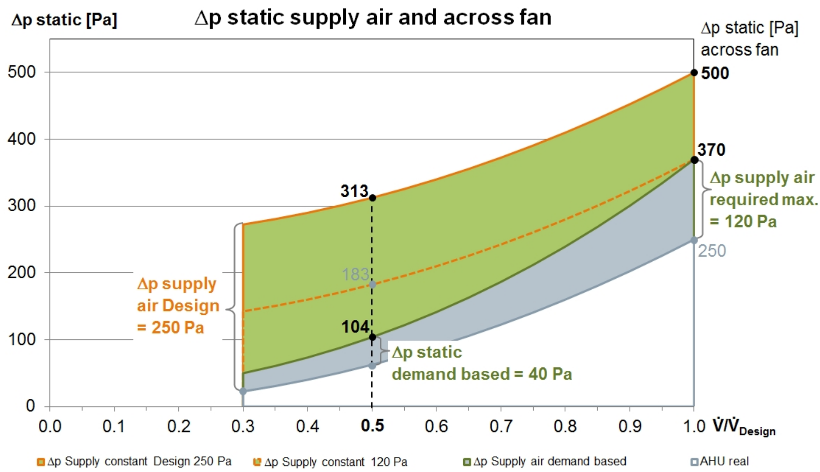


Fig. 5 VAV-system with "Demand based Supply air pressure control" – VAV dampers are open as much as possible with adequate duct pressure

Fig. 5 shows the setup of a state-of-the-art „Demand based supply air pressure control". This control approach utilizes the communication possibilites of the BACS for gathering the VAV damper positions of all the associated rooms. This information is then analyzed and wheighted (if desired). Based on this analysis the static supply air pressure set point is continiously being reset in order to provide just the adquate static pressure to the ductwork. With this approach the VAV dampers are as much open as possible (e.g. in Fig. 5 in Office 2 at 85%).

With the demand based approach, not only the static pressure to the ductwork gets reset, also the static pressure across the fan is automatically adjusted to the required level. In Fig. 6 at max. air flow, Δp static across the fan up to the pressure sensor is actually at 250 Pa vs. 450 Pa (700 Pa -250 Pa) envisioned during the design phase.

Fig. 6 illustrates that the „Demand based supply air pressure control" only requires 104 Pa of static pressure across the fan and the corresponding power consumption of the fan is at a very low 0.34 kW. By applying this enhanced control approach and by adjusting the initially required static pressure to the actual plant and system needs, substantial reduction of power consumption (- 64%) results!



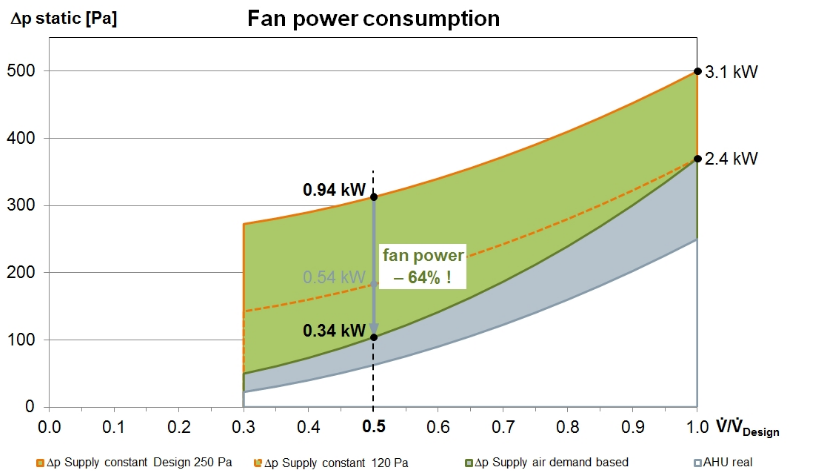


Fig. 6 Static pressure and related fan power consumption with constant vs. demand based static pressure control at design level and at optimized operating levels

3. Fan Energy Savings and Reduced Risk of Noise Issues

Accumulated power consumption reduction per year due to demand based fan control is (at avg. 50% air flow) operating from 06:00 – 18:00,
250 days per year: 0.6 kW · 12h · 250 days = 1'800 kWh/a for one fan.

For the six AHUs in this building with a supply air and a similar return air fan (90% power of supply air fan) this equates to reduced power consumption of about 20'500 kWh each year.

Furthermore due to the much lower static pressure in the duct work, the VAV systems are much less prone to noise problems in the rooms caused by VAV dampers that are undesirably closing too much.

4. Measured Data From Investigated Building

In an Air Handling Unit with related VAV boxes for various offices and meeting rooms, values for damper positions and fan power consumption were gathered over several days at comparable operating conditions with the two different control approaches discussed above:

- Constant Δp supply/return air pressure control – as in Fig. 4 – adjusted to actual plant needs at 120 Pa (not design value 250 Pa)
- Demand based Δp supply air pressure control and optimized for maximum possible damper position – as in Fig. 5 – operating at an average of about 40 Pa

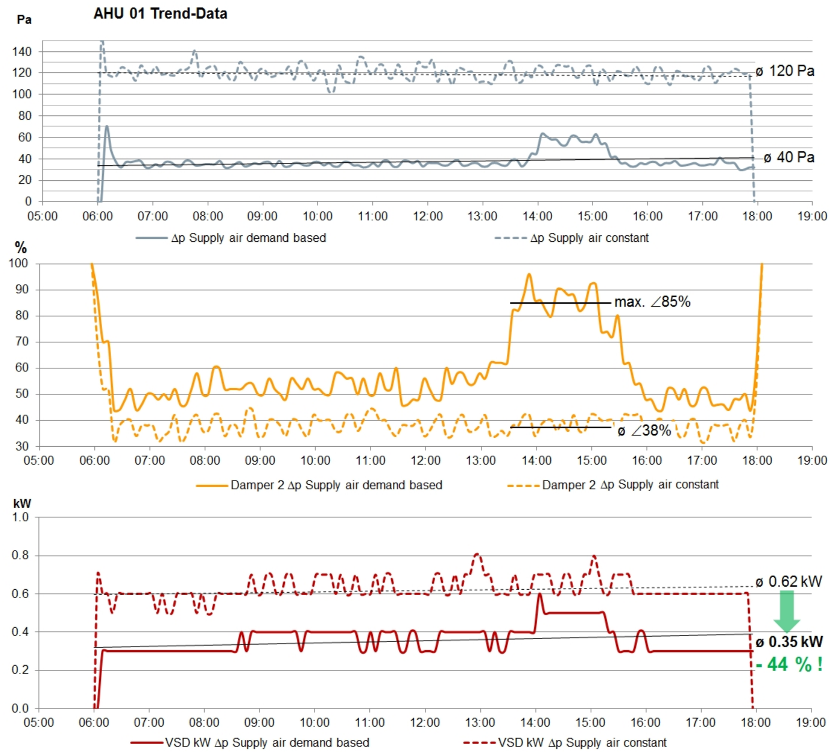


Fig. 7 VAV damper positions and substantially reduced fan power consumption (-44%) with Δp supply air demand based (avg. 40 Pa) vs. Δp supply air constant (120 Pa) controls

5. Theoretical Savings vs Actual Fan Power Reductions

The trended data described above clearly shows that by applying state-of-the-art demand based fan speed control the fan power consumption will be reduced substantially by 44%. This is achieved by constantly resetting the supply/return air pressure to maximize VAV damper positions (VAV box that is open the most is at e.g. 85% open).

The achieved power consumption reduction in the actual plant on typical days of operation compares nicely to the theoretical reduction (see Fig. 6, from 0.54 kW down to 0.34 kW) discussed above.

Table 1 Theoretical vs. actual fan power consumption reductions

Controls approach	Theoretical consumption at $\dot{V}$ 50%	Average consumption over 1 day
Constant Δp static	0.54 kW	0.62 kW
Demand based Δp	0.34 kW	0.35 kW
Fan power reduction	- 37 %	- 44 %

6. Proven Software Functions for "Demand Based" Control Approach in BACS Minimize Project Costs and Reduce Risks

Such state-of-the-art demand based fan speed control approaches fully utilize the capabilities of today's communicating Room Automation- and VAV Compact-controllers in an integrated Building Automation System.

In order to minimize engineering, start-up and commissioning efforts, proven software functions are provided in the BACS software. A project engineer simply assigns the relationships between the controllers of the various VAV boxes and the corresponding AHU fans and adjusts the relevant parameters where needed, however no programming is required for that. The software functions then utilize predefined communication objects (e.g. BACnet, KNX, Modbus) in a standardized and well tested way.

The initial settings and parameters for these software functions in the utilized BACS have been established in a joint effort by the "Fraunhofer Institute IIS, Workinggroup SCS" in Nuremberg [4] and the controls manufacturer. The parameters have been optimized regarding energy consumption, controls quality and also wear of the components (e.g. damper actuators) so that for the relevant plants and the various load situations a robust control behavior could be achieved.

7. Conslusion

This study clearly shows, that by applying an integrated "demand based" controls approach as described above (vs. a traditional "constant supply air pressure control"), substantial reductions of fan power consumption can be achieved. In order to realize such a controls approach, the VAV-systems have to be designed and built for that. In this building this was achieved due to the foresight and the professionalism of the HVAC consultant and the building automation specialists.

The data from the office building also underlines, that power consumption reductions in the range of the theoretical reductions are achievable in reality. This by utilizing the communication capabilities and proven software functions in a state-of-the-art BACS.

Energy efficient controls functions are readily available in today's BACS. Utilize them in order to achieve substantial reductions in electrical power consumptions and by that achieving related cost savings throughout the lifetime of the plants and HVAC systems!

Acknowledgment

We would like to thank the owner of the office building in Norway for providing the possibility to conduct this study utilizing the VAV systems during normal hours of operation. Furthermore we would like to thank the team of controls application developers from the BACS manufacturer for their valuable contributions and reviews. Our thanks are also extended to Dr. Jürg Tödtli for sharing his papers (see [2, 3]) and his vast controls experience with us.

References

[1] EN 15232:2012 "Energy performance of buildings - Impact of Building Automation, Controls and Building Management"
[2] Dr. Jürg Tödtli. "The impact of control on the energy use of fans in building ventilation systems". REHVA HVAC Journal 05/2015
[3] Dr. Jürg Tödtli. "Die dritte Potenz: ein Mythos? – Der Einfluss der Gebäudeautomation auf den Energiebedarf von Ventilatoren in HLK-Anlagen", 18. Status-Seminar „Forschen für den Bau im Kontext von Energie und Umwelt", ETH Zürich, 4./5. September 2014.
[4] Dipl.-Math. Bettina Berning, Dr. Jens Wollenweber. "Optimierte Bedarfsregelung von Ventilatoren, Abschlussbericht: robuste Parametereinstellungen" Fraunhofer Institut IIS, Arbeitsgruppe SCS, Nürnberg, 08. April 2010
[5] Plüss, Iwan, Menti Urs-Peter. "VAV Optimizer, Ermittlung des energetischen Einsparpotentials" Hochschule Luzern, Technik und Architektur, Oktober 2005.