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Functional performance check of Demand Controlled Ventilation - The load tests Max-max-min and Min-min-max

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Abstract

The Total Concept method uses a systematic approach throughout the whole building process of the energy retrofit. The method is divided in to three main steps where the last step involves functional performance checks. One relevant measure is to convert existing Constant Air Volume (CAV) to Demand controlled ventilation (DCV). DCV means systems that automatically regulate the ventilation rate according to a demand measured at room-level. The room ventilation rates are regulated with VAV-units (Variable-Air-Volume - damper). The purpose of functional performance check is to reveal inadequate performance within the full operating range of the air handling unit (AHU) and the VAV-units. The full operating range means from minimum system-load (typically empty building) to maximum system-load (design load) for the AHU and from minimum airflow (Vmin) to maximum airflow (Vmax) for all the VAV-dampers. Functional performance checks carried out for these operating situations will reveal most types of inadequate performance. We recommend checking all the VAV-dampers with the Max-max-min and Min-min-max load tests.

The Max-max-min load test is a functional test of the demand controlled ventilation system at the maximum airflow rate the AHU is designed for. Each VAV-damper is controlled for Vmax and Vmin at this load. The Min-min-max load test is a functional test of the demand controlled ventilation system at minimum airflow rate the ventilation system is designed for. Each VAV-damper is controlled for Vmin and Vmax at this load.

Keywords - Total Concept, Demand Controlled Ventilation, Performance check, Commissioning

1. Introduction

In order to reach the 20-20-20 EU-targets it is essential to increase the ambitions of the property owner´s to make refurbishment towards nearly zero-energy buildings. Most existing non-residential buildings have a potential to reduce energy use in a profitable way.

A method called the Total Concept, has been developed and successfully applied on a number of non-residential buildings in Sweden. The Total Concept method uses a systematic approach throughout the whole building process of the energy retrofit [1, 2]. The method is described into three main steps:

1. In Step 1 a comprehensive inventory is carried out in the building to identify all conceivable energy saving measures. Analyses of energy savings and costs are presented into an internal rate of return diagram that gives information on how to choose a package of energy efficient measures that met the owner's requirements of profitability.
2. In Step 2 the implementation of the package of energy efficient measures in the building is carried out. The focus needs to be on the quality of the work, and to make sure that designed intent will lead to the expected energy savings. Here functional and performance checks are significant in order to reach the expected results. Beside the added functional and performance checks of the building services, the process is basically the same as in any normal construction project.
3. In Step 3 the follow up of the implemented measures is performed, and involves measuring and checking procedures to ensure that the expected result of energy performance has been achieved. The energy use during at least one year after is compared to the energy use before implementation of the action package.

The Total Concept has during the last years been tested on several non-residential buildings in Sweden. Only a few buildings have results from all three steps of the method, but experiences have now been collected and analyzed for step 1 of several projects.

One relevant measure is to convert existing Constant Air Volume (CAV) to Demand controlled ventilation (DCV). DCV means systems that automatically regulate the ventilation rate according to a demand measured at room-level. The room ventilation rates are regulated with VAV-units (Variable-Air-Volume - damper). Studies show that energy use for ventilation purposes can be reduced by more than 50% with DCV compared to CAV [3].

An analysis of 13 office buildings that have done step 1 of the Total Concept shows that the measure to upgrade the ventilation system and install demand controlled ventilation is on the top of the list for packages of measures [4]. This means that the measure is the most profitable that could be identified among all different kinds of measures in the office. An analysis of 16 schools that have performed step 1 of the Total Concept shows that after upgrade of the ventilation system and install heat recovery, demand controlled ventilation is the next most profitable measure [4].
A conclusion from the analysis is that installation of demand control ventilation will probably increase the coming years. However, in order realize this, the building owner need to have trust on that the calculated energy savings will be reached and the Total Concept therefore put large efforts in functional tests during step 2. A detailed description of how to perform a coordinated verification of functions and energy performance before the final inspection has therefore been developed in Sweden [5]. The method describes how to plan and carry out the coordinated performance check and who should be responsible but it lacks in detail on how to check the function of demand control ventilation.

In this paper a method for functional performance check is suggested and described. The experiences will be used to improve the quality of the Total Concept method.

2. Methods

The main methods are field studies, literature reviews together with simulations. These have been carried out in the R&D projects reDuCeVentilation [6], and UPGRADE Solutions [7]. The results are improved with experience from control of new DCV-systems. The functional performance check is adapted to the IEE Total Concept project and fit the Total Concept method.

3. Results and dicussion

Evaluation of real energy use demonstrates that DCV-based ventilation systems must improve their performance to close the gap between theoretical and real energy use [8]. This unfortunate experience with DCV seems to have many causes, but the consequences are typically insufficient capacity at maximum load, or lack of controllability or precision at minimum air flow rates.

The purpose of functional performance check is to reveal all kinds of inadequate performance within the full operating range of the air handling unit (AHU) and the VAV-unit. The full operating range means from minimum system-load (typically empty building) to maximum system-load (design load) for the AHU and from minimum airflow (Vmin) to maximum airflow (Vmax) for all the VAV-dampers.

For each of the two extreme system loads, it is necessary to consider each VAV unit and override the control signal from the room sensor (eg. CO_2 or temperature) to force the VAV unit to respectively max (Vmax) and min (Vmin) airflow rate, and document airflow rate and opening grade. Functional performance checks carried out at these four extreme points will reveal most types of inadequate performance [9].

4. The load tests Max-max-min and Min-min-max

The Max-max-min load test is a control of max and min airflow rate for each VAV unit at maximum load. The Min-max-min test is a control of max and min airflow for each DCV unit rate at minimum load. This requires four control measurements per VAV unit. Such a control procedure is particularly relevant for DCV systems with pressure control and limited control possibilities from the BMS (Building Management System).

The opening grade tells us whether the VAV units work in the favorable range (40 to 80%) and if the pressure set point is reasonable.

A special VAV-system performance check form is designed for this purpose (Fig. 1).

SINTEF — VAV-system Perfomance check

Building

System

Drawing Id.

Control date

Static Pressure Setpoint before balancing (supply/exhaust): Pa — *R = Measured airflow/design airflw*

Static Pressure Setpoint after balancing (supply/exhaust): Pa

Max-max-min load test — Total supply[m³/h]: / Fan power [kW]: / Total exhaust [m³/h]: / Fan power [kW]: / Largest total [m³/h]: - / SFP [= 3600 × ∑kW / (m³/h)]: -

Min-min-max load — Total supply[m³/h]: / Fan power [kW]:

Room/ zone	VAV-unit ID		Design airflows				Max supply local			Max exhaust local			Min supply local			Min exhaust local			Max tilluft lokalt		
	Supply	Ex-haust	Supply Vmax [m³/h]	Supply Vmin [m³/h]	Exhaust Vmax [m³/h]	Exhaust Vmin [m³/h]	Vmax [m³/h]	R	Positi. [%]	Vmax [m³/h]	R	Positi. [%]	Vmin [m³/h]	R	Positi. [%]	Vmin [m³/h]	R	Positi. [%]	Vmax [m³/h]	Vmålt/ Vprosj	Posisj. [%]
								-			-			-			-			-	
								-			-			-			-			-	
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Fig. 1 Recommended form for VAV system performance check. Only a part the form is shown for increased readability.

5. Procedure for the load test

A. How to carry out the Max-max-min test

The Max-max-min load test is a functional test of the DCV system at the maximum airflow rate that the AHU is designed for.

Work steps :

a) Force the VAV units in one part of the building to Vmax, so that the AHU's airflow rate increases to the design value (maximum system load), while the VAV units in the rest of the building are forced to Vmin.

b) In the part of the building where the rooms are forced to Vmax, go from room to room and control if the airflow rate through the VAV units (supply and exhaust) is equal to Vmax. These measurements are filled in the pink columns («Local max supply/exhaust»).

c) Next, repeat the control of the same rooms, but instead, force the VAV units to Vmin one room at a time, and control that the airflow rate falls to Vmin. These measurements are completed in the blue columns («Local min supply/exhaust»).

d) Now repeat steps (a) to (c) to control the rest of the rooms, i.e. rooms on the side of the building that was not forced to Vmax. For example, in a 10-story building with a common AHU, you can switch to force control the bottom 5 floors and the top 5 floors to Vmax.

B. How to carry out the Min-min-max test

The Min-min-max load test is a functional test of the DCV system at minimum airflow rate (i.e. minimum simultaneity) that the ventilation system is designed for.

Work steps :

a) Force all VAV units in the building to Vmin.

b) Move from room to room and control if the airflow rate through the VAV units (supply and exhaust) is equal to Vmin. These measurements are completed in the blue columns («Local min supply/exhaust»).

c) Then, repeat the control with VAV units to Vmax in one room at a time, and control that the airflow rate reaches Vmax. These measurements are filled in the pink columns («Local max supply/exhaust»).

C. Why test Vmin?

It is important to test Vmin for the following reasons:

• To check that Vmin is within the operating range of the VAV units.

• To test Vmin in all rooms except for one room with Vmax, confirms that the persons in this room actually get the air they need, for example when working overtime.

• To confirm that a low SFP value is achieved outside of normal operation time (night/weekend).

• To check that the DCV system is well-functioning at minimum load.

D. How to force all the VAV units in the building to Vmax and Vmin?

• A possible solution is to override the room control (change the set point on the temperature sensor/CO_2 sensor). Often, only the temperature signal has to be changed because it overrides the CO_2 signal. This can often be done centrally via the BMS. It is important to remember to set the set point back to the initial value after the test!

E. How to force a single room for testing of Vmax and Vmin?

• Option 1: For buildings with BMS, the VAV units can be forced to Vmax by changing the set point for room temperature to for example 10 °C or CO_2 to 100 ppm. Likewise, it is possible to the force the airflow rate to Vmin by changing the set point of CO_2 to 10.000 ppm and/or room temperature to 30 °C. The advantage of this option is that it also checks the integrity of the room sensor signal cable.

• Option 2: Otherwise, you can use dedicated software to override VAV units one by one. This is especially time saving when all the VAV units' bus signals are combined on the same board.

• Option 3: Use the dedicated handheld programming device to set Vmin to Vmax or the opposite. This option is not preferable, since one can forget to set Vmin or Vmax back to the original set-points.

F. How to measure the airflow rate?

There are several suitable methods of airflow rate measurement related to the documentation of maximum/minimum load testing:

• Option 1: Read the airflow rate which is recorded with the VAV units' own measuring station (readout via BMS, etc.). This method is fast but requires that the VAV unit's measuring station is accurate. This method is recommended for newer models of VAV units with favorable location (in compliance with the vendor's requirements in terms of minimum straight duct both before and after the VAV unit). The method is unsure for older models which were individually calibrated at the factory

• Option 2: Use the common Nordic methods (Johansson and Svensson, 2007), for example by measuring the airflow directly with a cone, or with a pressure sensor and k-factor over the diffuser, or a Pitot tube in the branch duct.

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References

[1] Åsa Wahlström, Agneta Persson, Karin Glader, Katarina Westerbjörk och Anders Göransson, Fallstudier till HEFTIG, , A Report to the Swedish Energy Agency, December 2015

[2] Göran Andersson, Fokusprojektet samordnad funktionskontroll – Steg 2, , A Report within the BELOK programme, May 2015

[3] Mari-Liis Maripuu. *Demand controlled Ventilation (DCV) systems in commercial buildings: functional requirements on systems and components*. Göteborg: School of Electrical and Computer Engineering, Chalmers tekniska högskola 2009.

[4] www.totalconcept.info

[5] Åsa Wahlström, Enno Abel and Mari-Liis Maripuu, " Total Concept-for better decision-making about Energy Efficiency Investments in non-Residential Buildings ", Accepted for proceeding of ECEEE Summer Study 2015, Toulon, France, paper 6-103-15, page 1239, 1 - 6 June, **2015**.

[6] www.sintef.no/projectweb/reduceventilation

[7] www.upgradebuildings.no

[8] Mads Mysen, Peter Schild, Axel Cablé, Demand-controlled ventilation – requirements and commissioning, SINTEF Research 24 Guidebook published by SINTEF (2014). . ISBN: 978-82-536-1414-4 (63 pp). Free down load at https://www.sintef.no/projectweb/reduceventilation/.

[9] Mads Mysen, Peter Schild, Finn Drangsholt, "Robustness and True Performance of Demand Controlled Ventilation in Educational Buildings – Review and Needs for Future Development". Proceedings In 31st AIVC Conference 'Low Energy and Sustainable Ventilation Technologies for Green Buildings'. October 2010, Seoul.