Robustness and True Performance of Demand Controlled Ventilation in Educational Buildings:

Review and Needs for Future Development

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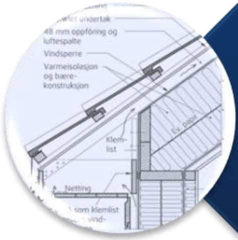
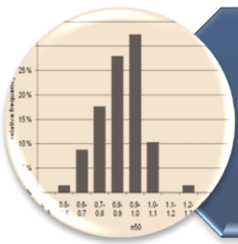


Building practices & design

Market transformation & costs



Airtightness requirements & statistics

Measurement & standardization

Why further research on DCV?

Pros

- important for health, well-being and productivity
- reduces energy for ventilation.

Challenges

- Reliability can be further improved
- Theoretical energy saving potential is seldom met

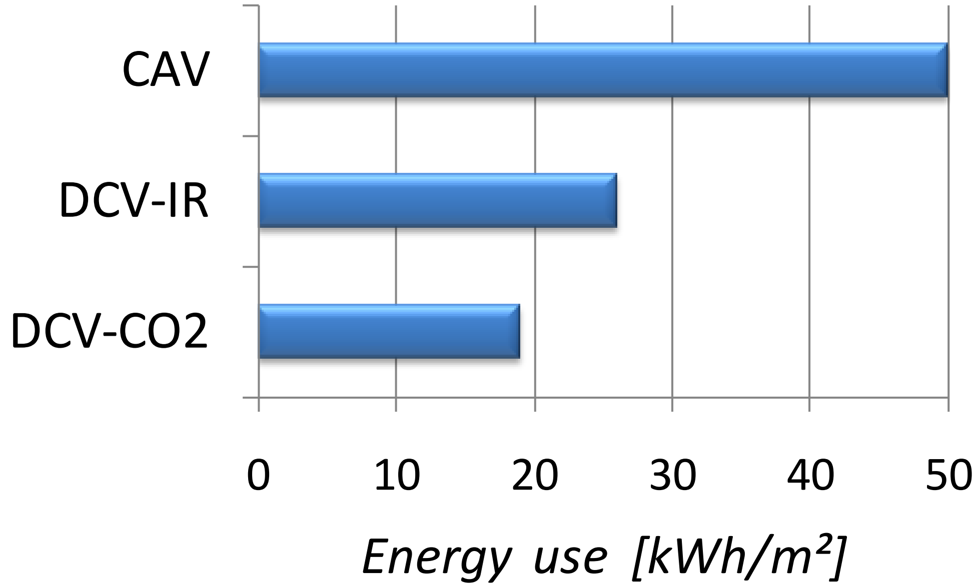
Potential - Inspection of 157 school classes in Norway

	Mean	Min.	Max.	Standard deviation
Pupils assigned to the class	22.3	13.0	28.0	3.5
Pupils present during inspection	20.9	13.0	28.0	3.6
Teachers present during inspection	1.3	1.0	3.0	0.5
Floor area of classroom [m^2]	61.5	43.0	93.0	8.2
Volume of classroom [m^3]	190.0	150.0	285.0	31.0
t_{use} - Use of classroom during inspection day [h]	4.0	3.0	5.0	0.4

[Ref. Mysen, Berntsen, Nafstad, Schild, *Energy & Buildings*, 2005]

Ventilation control and energy use

- 74% of classrooms max capacity used
- 4 hours use for school activities (12 normal operation)



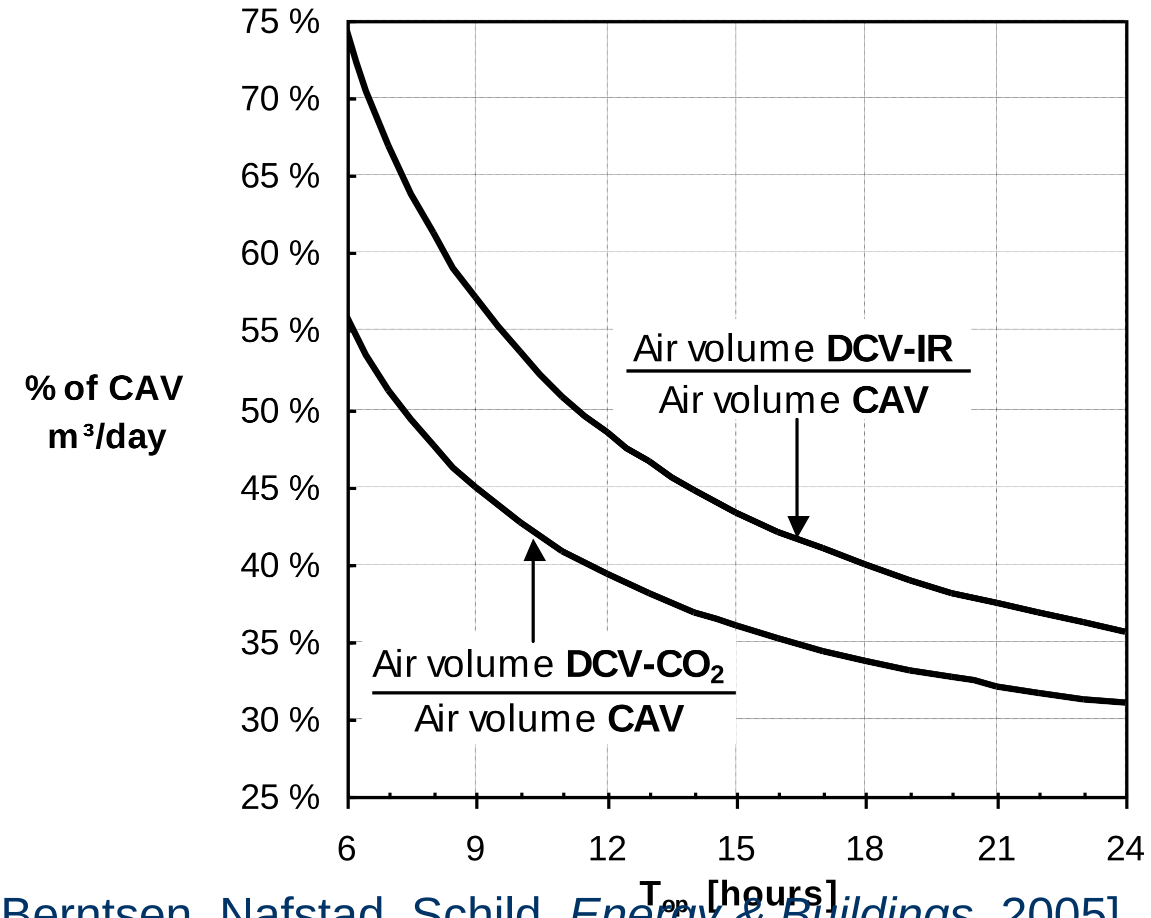
[Ref. Mysen, Berntsen, Nafstad, Schild, *Energy & Buildings*, 2005]

Ventilation control strategies

- CAV: 30 occupants - 7 ℓ/s·person and an additional 1 ℓ/s·m²
- DCV-CO_2: Actual number of occupants. The ventilation rate is then increased and regulated to keep the CO_2 concentration at a steady state level of 900 ppmv. Minimum airflow of 1 ℓ/s·m² when the CO_2-level is less than 700 ppm.
- DCV-IR: 30 occupants - 7 ℓ/s·person) plus an additional 1 ℓ/s·m². Minimum airflow - when the classroom is unoccupied. Design airflow when the classroom is in use.
- Fan energy and heating energy

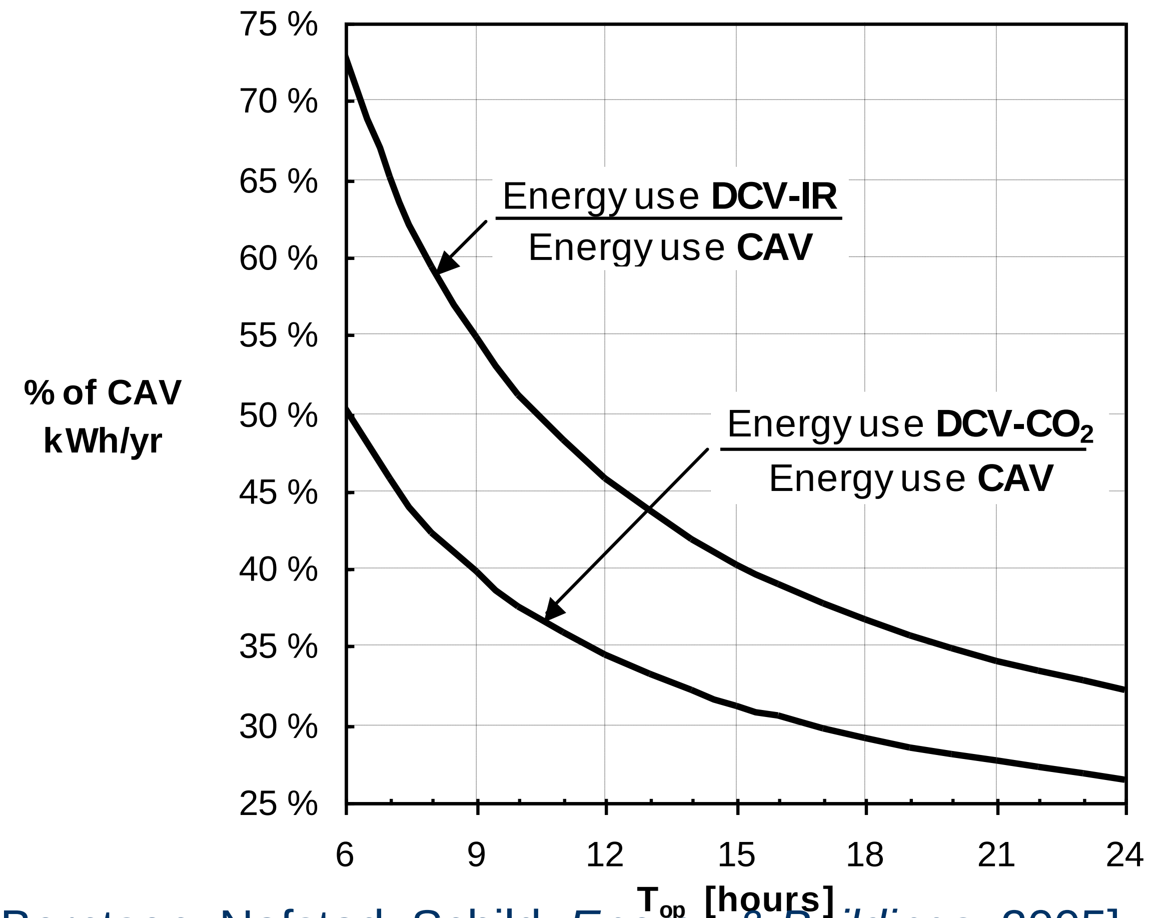
[Ref. Mysen, Berntsen, Nafstad, Schild, *Energy & Buildings*, 2005]

AHUs operation period and ventilating air volume in % of CAV



[Ref. Mysen, Berntsen, Nafstad, Schild, *Energy & Buildings*, 2005]

AHUs operation period and energy use in % of CAV



[Ref. Mysen, Berntsen, Nafstad, Schild, *Energy & Buildings*, 2005]

reDuCeVentilation - Main target

Help the Norwegian construction sector to utilize the potential to reduce energy use with demand controlled ventilation in schools by dissemination of guidelines supplementing the Norwegian building code and building standard NS3031.

reDuCeVentilation - Sub targets

- Perform a rough review of previous research on ventilation rates and health effects, well-being and risk of building construction damage in schools.

- Perform review of previous research
  - occupancy factors and corresponding ventilation air flow rates and energy use in schools
  - demand controlled ventilation system including sensor technology and internal communication technology

- Establish knowledge about the use of modern indoor school areas to decide important parameters like density (people/m2), time of use, operation time of air-handling-units, ventilation system and energy saving potential optimal sensor choice and ventilation system design.

reDuCeVentilation - Sub targets cont.

- Establish a validated tool for simulation of the energy saving potential in schools, that will serve as appropriate documentation according to NS 3031.
- Evaluate a strategy for controlling the ventilating airflow rate with an indoor temperature-compensated CO_2 set point
- Evaluate other possible control-parameter combinations
- Identify barriers towards DVC in general and indoor temperature-compensated CO_2 set point in particular.

reDuCeVentilation - Sub targets cont.

- Make guidelines for well-functioning and lifetime robust demand controlled ventilation in schools with optimal use of control parameters, sensor localization.

- Perform cost - benefit analyses of demand controlled ventilation in schools and office building and establish key profitability data and make the results easy accessible for the decision makers and applicable for early stage evaluation.

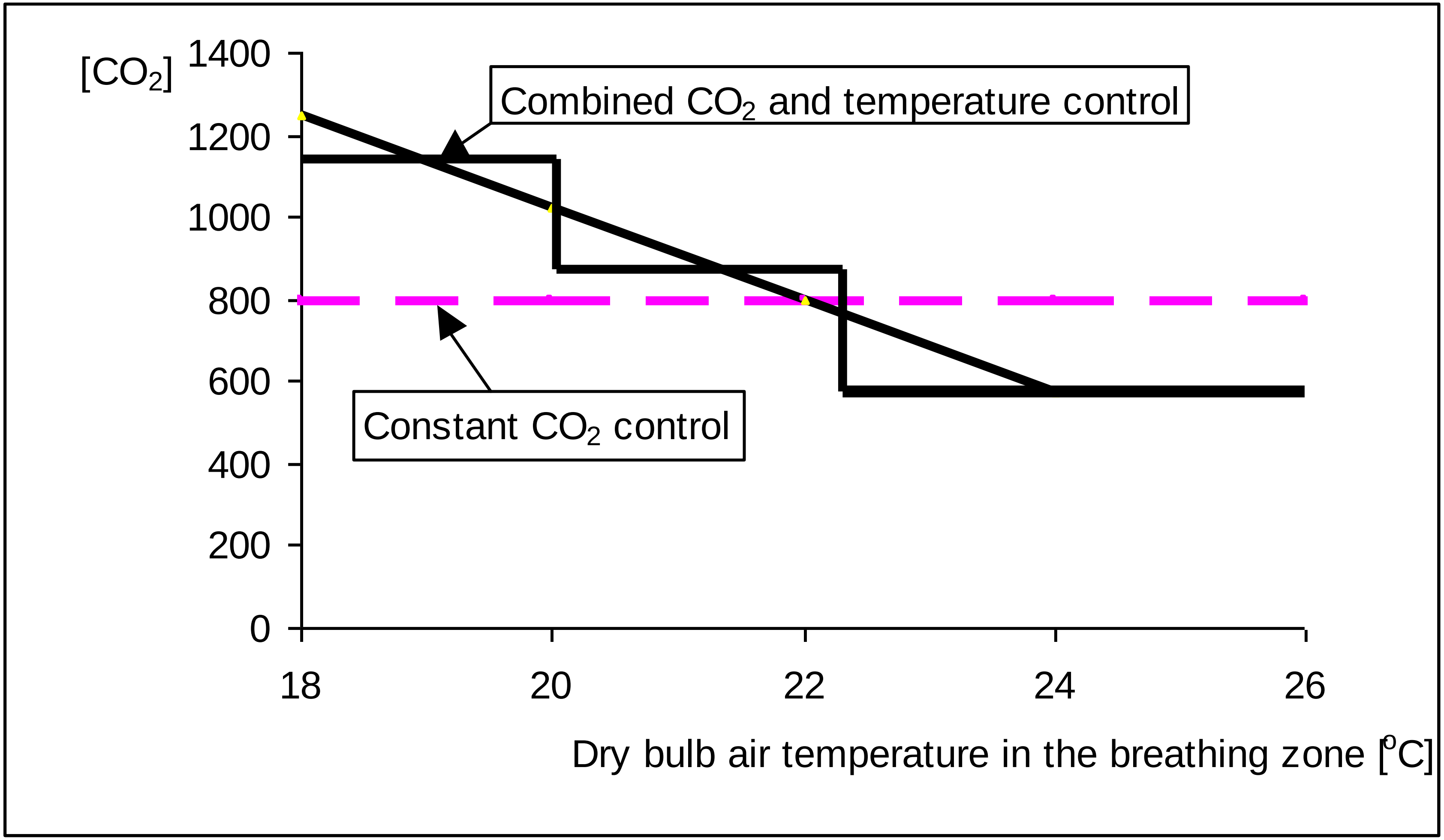
reDuCeVentilation

The project is interdisciplinary and will contribute to more energy efficient ventilation system technology, indoor environment knowledge, and sensor and communication technology.

Research approach, methods

- *Literature reviews*
- *Field studies*
- *Analyses*
  - The results of the field study will be analyzed with statistical tools leading to relevant input data for calculation of energy saving potential controlled for not relevant parameters. The need for sensibility analyses will be continuously considered and, if necessary performed.
  - The energy saving potential will be analyzed base on the field study results. The variation of the energy potential including relevant uncertainty will be analyzed with statistical tools.
- *Compose tools*
  - Establish a validated excel based tool for simulation of the energy saving potential in schools that will serve as appropriate documentation according to NS 3031. The tool should give necessary input data for design, management and maintenance of the DCV system.
  - Establish guidelines and a excel based cost-benefit tool for decision makers applicable in the early stage of a project.
- *Validation in field and laboratory*

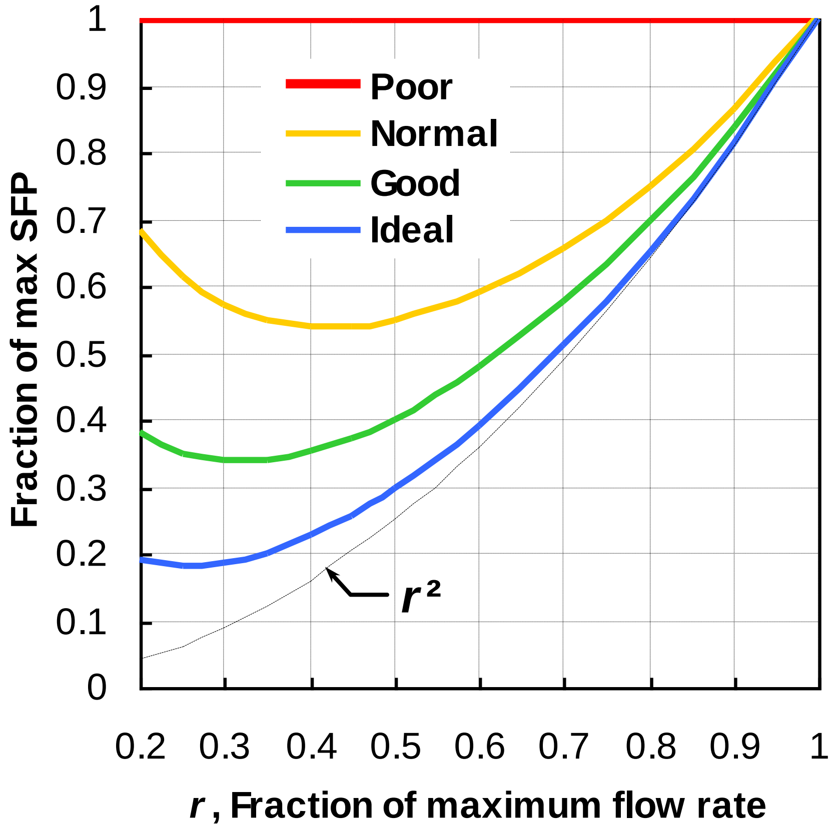
Combined CO_2- and temperature control

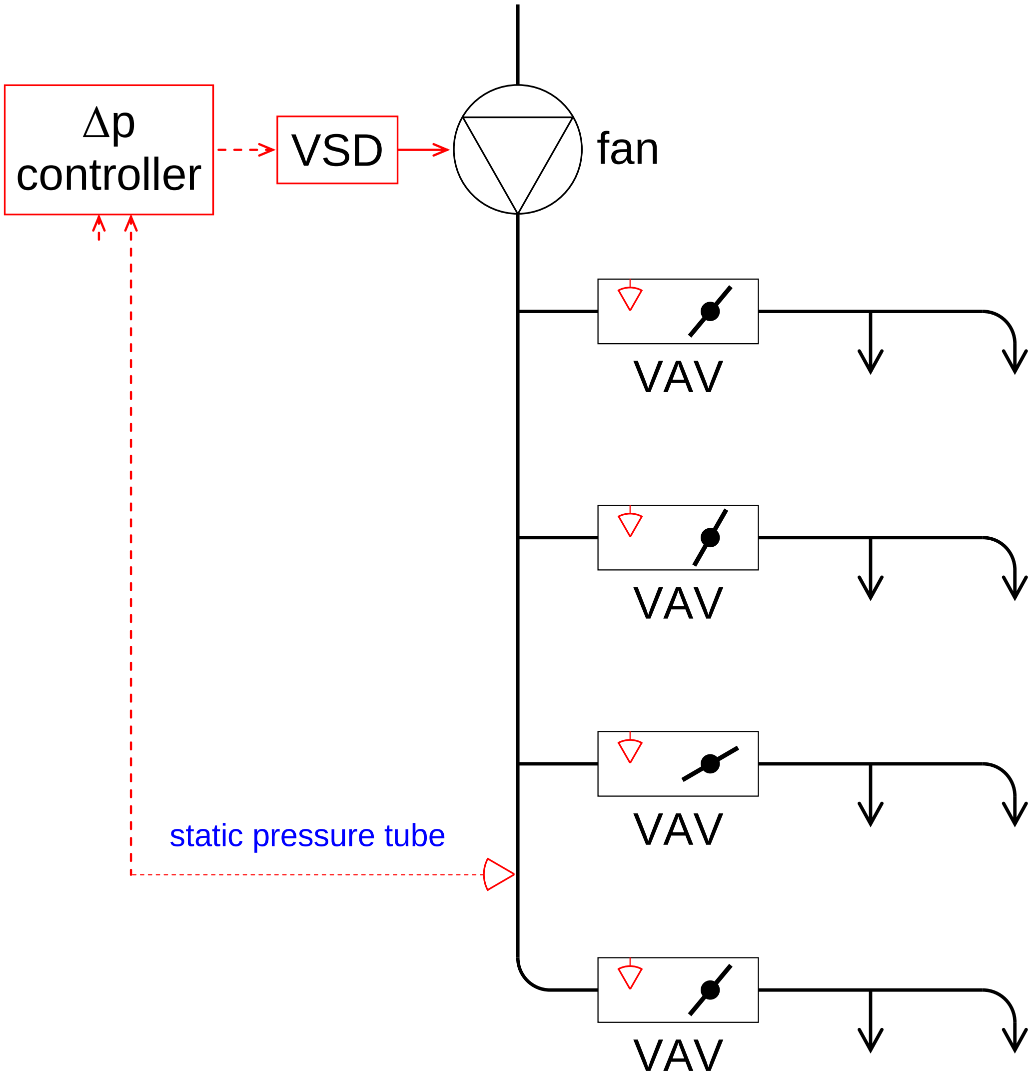


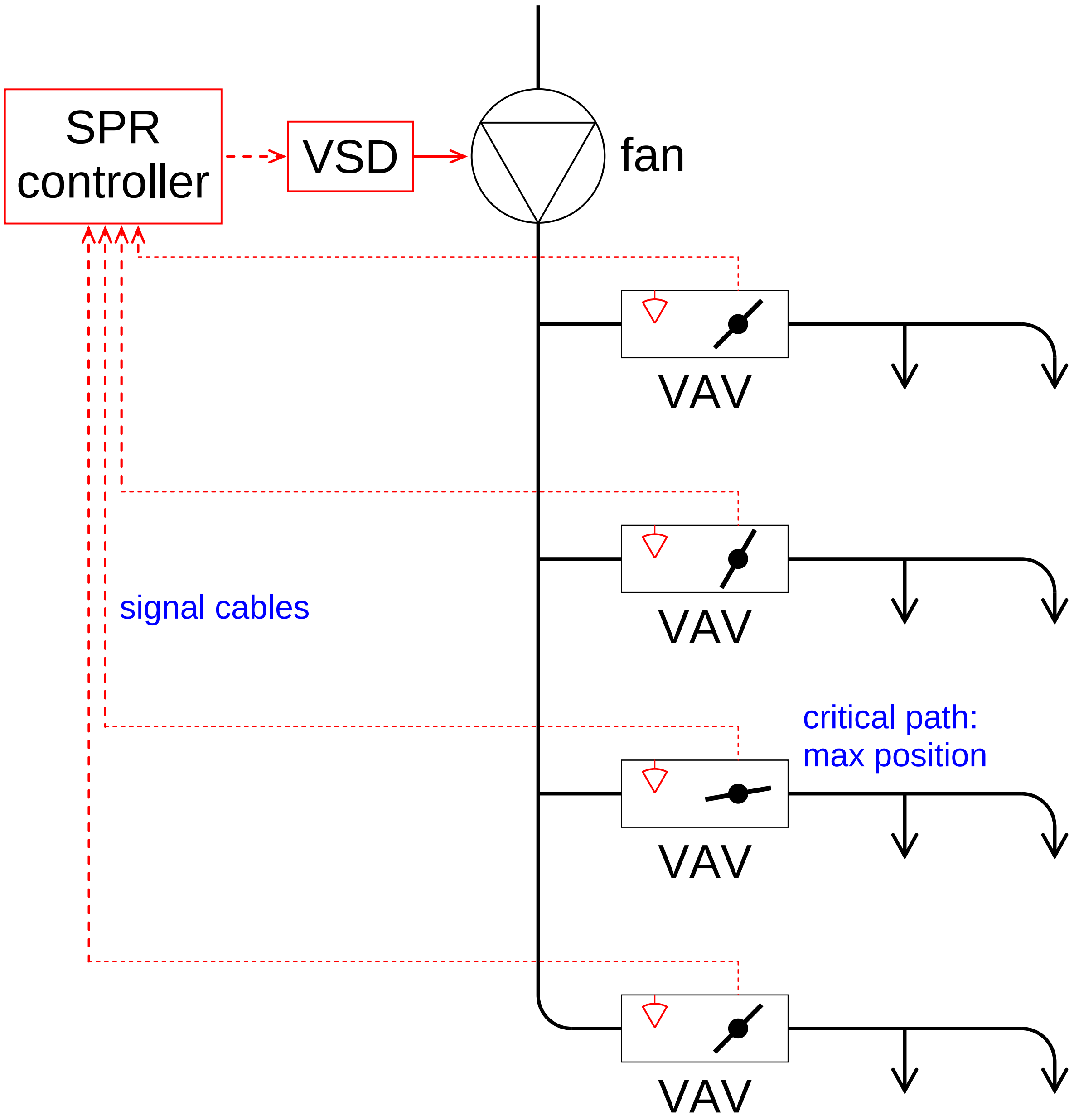
DCV-system and energy use

$$\overline{SFP}_e = \frac{\sum_{i=1}^{N}\left(\Sigma P_i\,\Delta t_i\right)}{\sum_{i=1}^{N}\left(q_{v,i}\,\Delta t_i\right)} = \frac{\sum_{i=1}^{N}\left(SFP_{e,i}\,q_{v,i}\,\Delta t_i\right)}{\sum_{i=1}^{N}\left(q_{v,i}\,\Delta t_i\right)}$$

$$\eta_{tot} \cdot SFP = \Delta p_{tot}$$




Δp
controller
VSD
fan
VAV
VAV
VAV
VAV
static pressure tube


SPR
controller
VSD
fan
VAV
VAV
signal cables
critical path:
max position
VAV
VAV

Results - success criteria for well functioning DCV

- The responsibility for the overall systems functionality is clearly defined and placed
- Up-dated knowledge about DCV among decision makers, designers, contractors and operating personnel. It especially crucial that it is designed by a HVAV-consultant with updated expertise within DCV
- Interactive systems communicate smoothly
- Adequate specifications, hand-over documentation and balancing report for DCV have been used

Results - success criteria for well functioning DCV

- Components, like sensors, that have proper functionality and quality throughout their predicted lift expectancy
- Possibility to control the function of crucial components like fan energy use, VAV-valve positions, air flows at room level etc.
- Maximum simultaneous use for design and assumed average use for energy calculations are together with specified running condition during control procedure.
- Prospective economical penalty is agreed upon before performance test during final control procedure