Technical article

Sensible use of energy-saving fans

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Main topics:

The first part of the presentation gives basic information for evaluating the energy efficiency of a fan:

- Different fan designs
- Efficiency of fan blade and motor
- Useable pressure and air flow losses
- Overall efficiency
- Driving power of fan and power consumption of motor

In the second part, possibilities are shown for saving energy for the fan driving power:

- Selection of fans with low speed
- Reduction of speed with suitable control systems
- Technical comparison of control systems
- Cost comparison of different concepts
- Fans with EC fans or Owlet fan blades

First published: 2007

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Foreword

In order to make a statement about the sensible use of energy-saving fans, it must first be explained what energy-saving fans are.
Are they just the most recent fan manufacturer's developments with EC motors or owlet blades?
These technical developments improve the efficiency of the motor and the blades. The amount of efficiency improvement depends on the state of technology with which they are compared. It is not just a case of having an EC motor or a high-tech blade, but the choice of the best fan and operating method also has a considerable influence on the energy cost. The fan type and the operating method thereof must be optimised before additional energy costs can be saved using high-tech motor and blade solutions.

Contents:

1. Different fan designs

In refrigeration and air conditioning engineering, axial fans are used for low and medium pressures, and radial fans are used for high pressures.

Axial fans for high delivery quantities and low pressures have long blades and a small hub diameter.
If higher pressures have to be built up using axial fans, running wheels with larger hub diameters are required.
The drive motors are either integrated in the running wheel hub (external rotor motor), or standard motors with flange-connected blades are used.

Radial fans are used in the form of housing fans or free-running wheels.
A basic distinction is made between running wheels with blades that are bent forwards for high delivery volumes, and moderate pressures, and running wheels with blades that are bent backwards high pressures in special applications.
The running wheels are driven directly or via V-belts.

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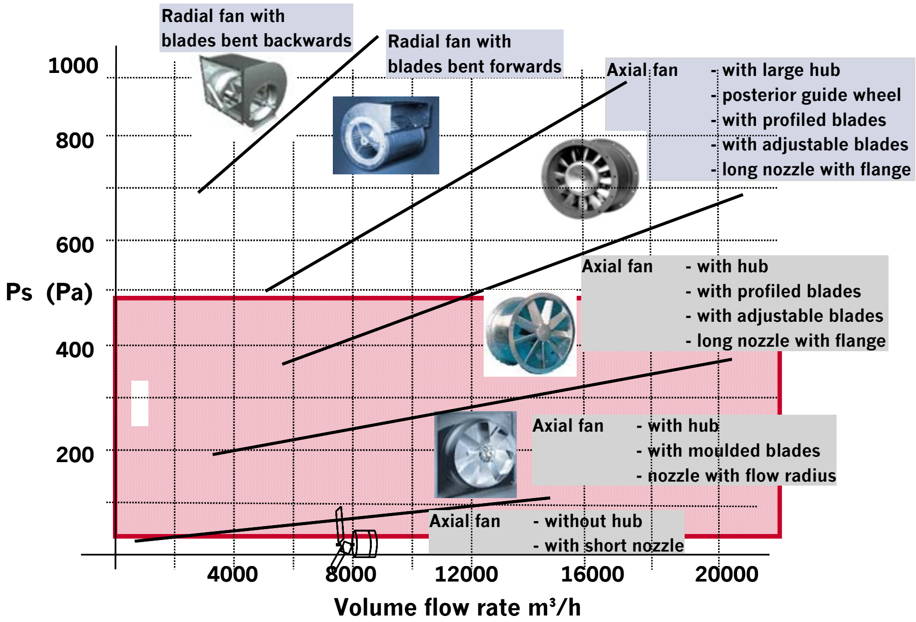
Graphic 1:
Overview of fans in refrigeration and air conditioning engineering



Fans with high delivery volumes are mainly needed in refrigeration and air conditioning engineering for pressure differences between 50 and 200 Pa.
Axial fans with small to medium-sized hub diameters and long blades are particularly suitable for this application.
Radial fans are only used for special applications with air ducts.
This lecture will concentrate on axial fans for low to medium pressures.

2. *Blade and motor efficiency*

The most important parameters for selecting a fan are:

- Volume flow (m³/h)
- Static pressure increase (Ps to Pa)
- Sound pressure level (db (A))
- Temperature

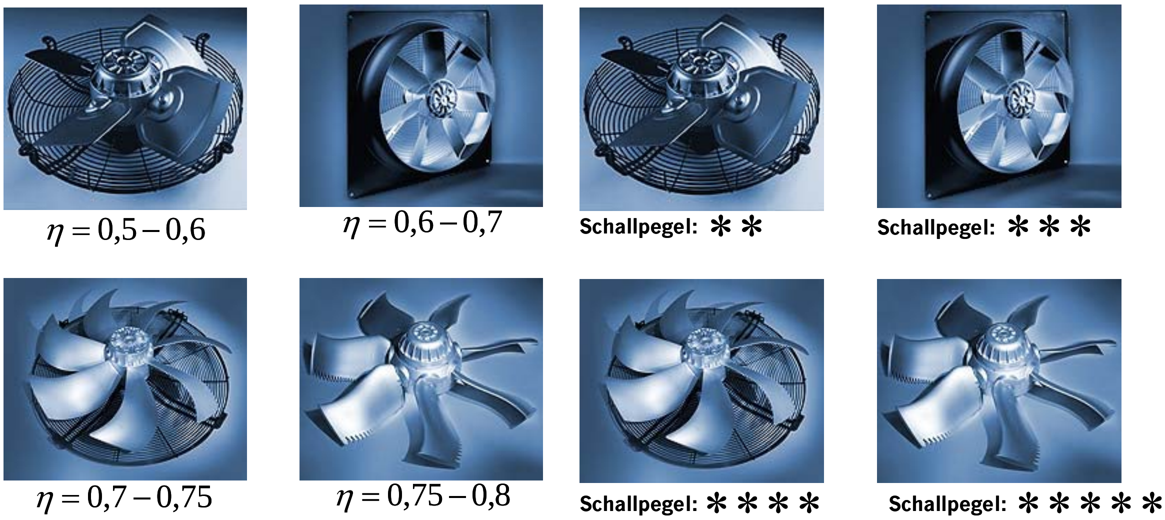
Mechanical, electrical and flow-related losses occur in the fan in order to deliver a volume flow and build up pressure. These losses must be minimised in order to produce high energy efficiency.

2.1 Blade efficiency

Simple running wheels have profile-less metal blades (efficiency approx. 50 – 60 %).
Optimised running wheels have profiled blades (efficiency approx. 60 – 70 %).
High-quality running wheels have profiled crescent-shaped blades to reduce the noise power level and optimise the efficiency (efficiency approx. 70-75 %).
The most recent developments have winglets on the blade tips to optimise the efficiency and fanned tearing edges to reduce the noise level even further (efficiency approx. 75 – 80 %).
The acoustic power level of the running wheel types varies in a similar way to the efficiency, i.e. profiled crescent-shaped blades are quieter than simple blades without a profile.

Figure 1: Fan blade efficiency level comparison

Fan blade acoustic power level comparison



2.2 Motor efficiency level

Different types of motor are used to drive axial fans, depending on the size and use.
The most important types are: split-pole motor, asynchronous motor (AC motor) and EC motor.

Split-pole motor
The split-pole motor is a simple, low-cost motor for small fans with drive power of up to approximately 30 W. The efficiency level is approximately 15 – 30 %.

Asynchronous motor – as external rotor motor
Fans with an external rotor motor are common in Europe in condensers and standard air coolers.
The motors are integrated in the hub of the fan. They have a soft characteristic curve, gentle start-up behaviour, good heat emission above the fan blades and the voltage thereof can be controlled.
The motor dimensions are limited by the size of the ventilator fan hub.
Normal size: up to 3.6 kW, fan diameter: up to 1000 mm.
Efficiency of external rotor motor as AC motor: approx. 60 - 70 %.
Efficiency of external rotor motor as three-phase current motor: approx. 70 -80 %.

Asynchronous motor – as separate motor with standard design
These motors are used for axial fans with a separate running wheel or belt-driven radial fans. Size: approx. 0.5 – 11 kW.
Efficiency: approx. 70 -80 %.

EC motor – as external rotor motor
The EC motor is a DC motor with shunt characteristics and integrated electronics. Induction losses are minimised by a permanent magnet in the rotor, and a high efficiency level is achieved.
The integrated power electronics convert the three-phase current into a DC current. This allows the motor to be connected and adapted to different power supplies.
The integrated control electronics include motor monitoring and a speed controller for control via the pressure, the temperature or a standard 0-10V signal.
Each EC fan must be parameterised for the power supply and the control characteristics prior to installation.
Size: up to 5,5 kW
Efficiency: 84 –90 %.

Figure 2: Fan motor efficiency level comparison

Split-pole motor

η= 15-30 %

AC external rotor motor

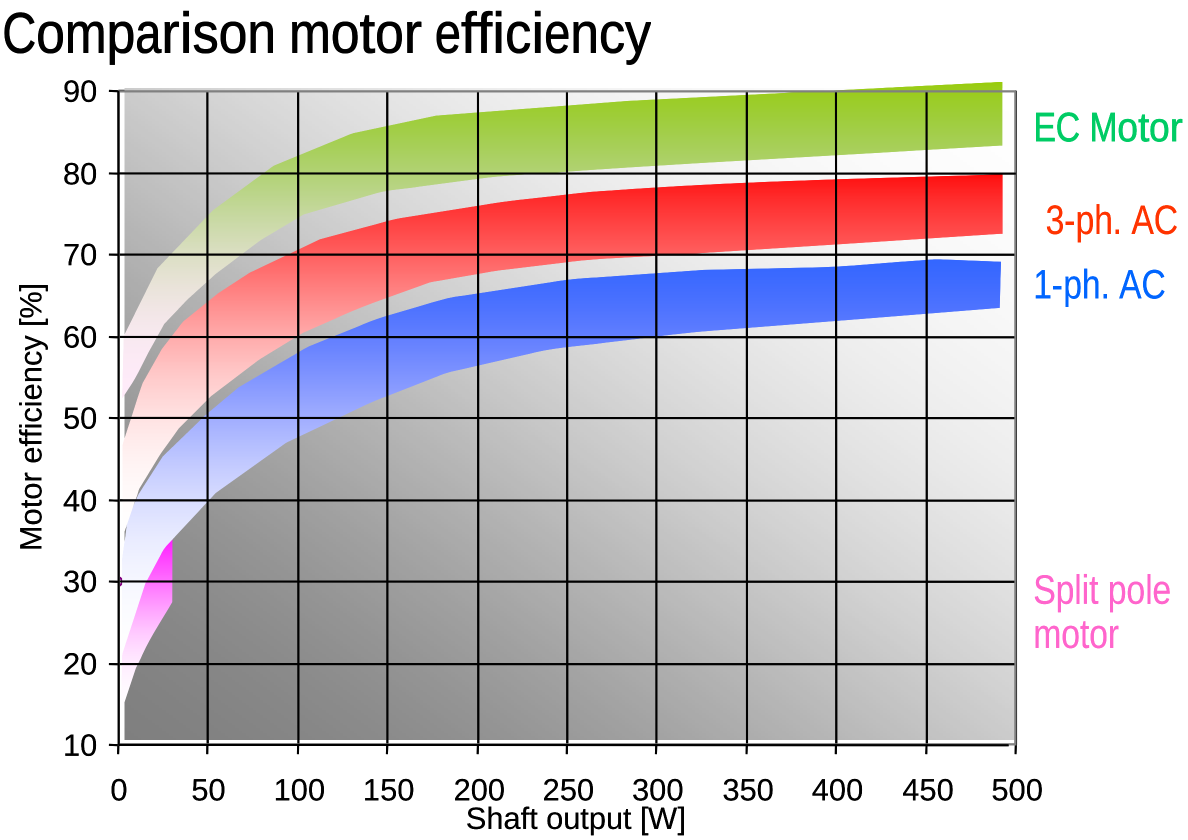
η 1 Ph= 60-70 %
η 3 Ph= 70-80 %

AC standard

η= 70-80 %

EC external rotor motor

η= 84-90 %



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3. *Static and dynamic pressure*

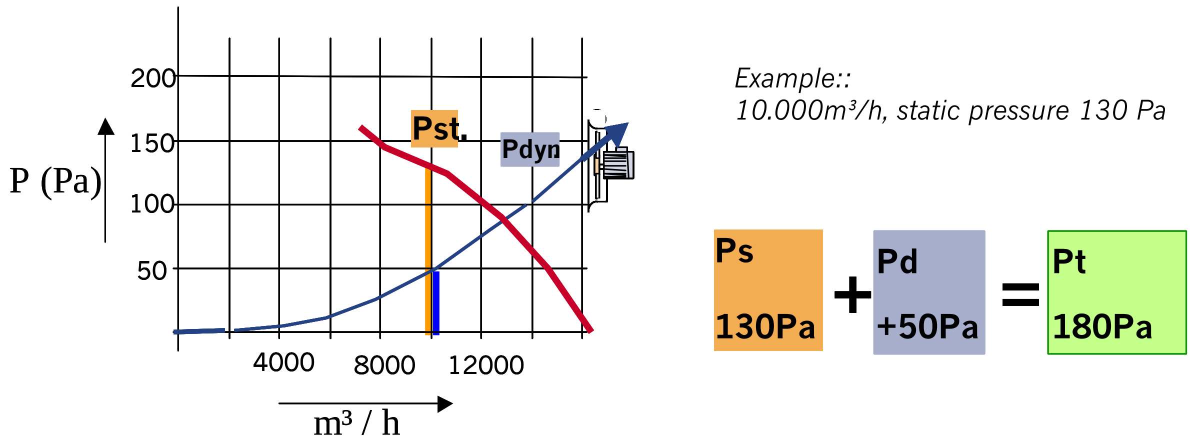
Static pressure Ps
= Usable pressure
Also referred as external pressure.
This pressure is needed for the system-related pressure losses, e.g. in air coolers and air ducts.

Dynamic pressure Pd
= Fan-related flow losses
In order to deliver the air volume, the air must flow through the fan nozzle via the running wheel at high speed. This results in fan-related flow losses. These flow losses are the dynamic pressure and must be carried out as additional fan work.

Total pressure Pt (Pt=Ps + Pd)
= The total pressure difference to be provided by fan.
The total pressure is the sum total of static and dynamic pressure.
For the calculation of the driving power its nessesary to use the Total Pressure Pt

In order to save energy it is therefore important to select a fan with a large proportion of static pressure and as little dynamic pressure as possible.
This can be achieved by selecting fans with a large diameter and a slow speed.

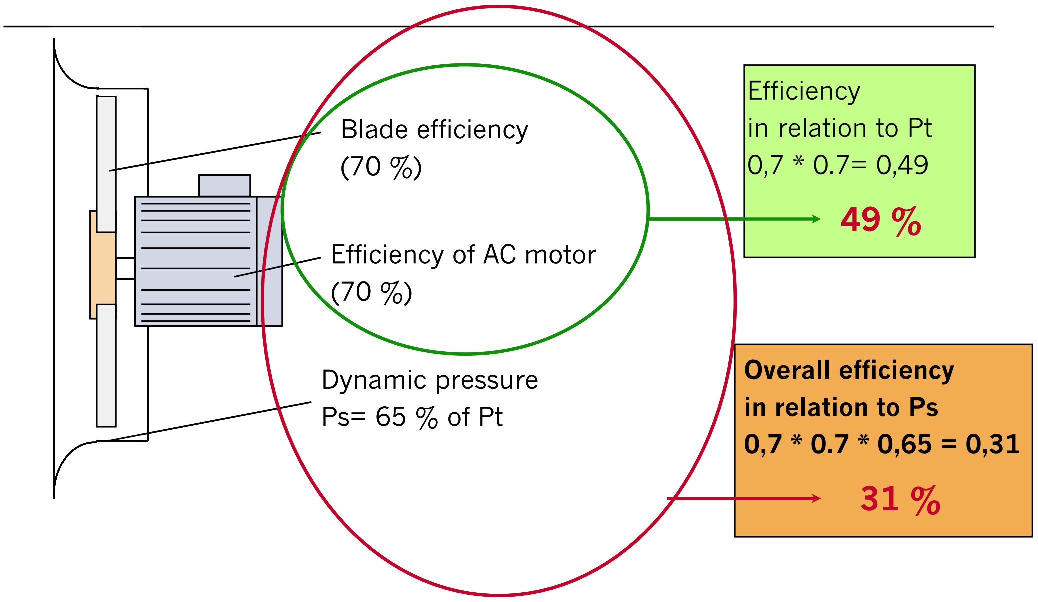
Figure 3: Static and dynamic pressure



4. *Overall efficiency*

4.1 Overall efficiency level of a fan:
The energy efficiency of a fan is shown by the overall efficiency level.
The overall efficiency level consists of
- Blade efficiency
- Motor efficiency level
- and flow loss (Ps / Pt, = static pressure / total pressure).

Figure 4: Efficiency level definition



Example of a not optimised system:
Blade efficiency level 0.7
Motor efficiency level 0.7
Ratio of static pressure to overall pressure 0.65
= overall efficiency level 0.31

This system has a usable fan efficiency level of 31 %.

Example of a technically optimised system:
Blade efficiency level 0.8
Motor efficiency level 0.9
Ratio of static pressure to overall pressure 0.72
= overall efficiency level 0.51

The fan efficiency level of the optimised system is 51 %.
The energy saving based on system 1 is 40%.

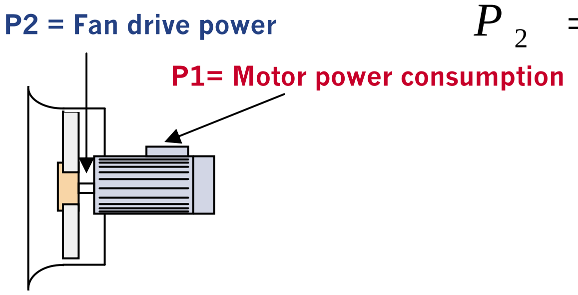
This shows that it is not just the motor or the blade that has a decisive effect on energy efficiency, but also the dynamic pressure loss of the fan.
The following are required in order to optimise the efficiency level:
-low dynamic pressure loss (large fan diameter and slow speed)
-good blade efficiency level (profiled blades, crescent shape)
-good motor efficiency level (EC motor or AC motor with controller combination with good partial loading behaviour)

5. Fan drive power and motor power consumption

5.1 Power consumption of a fan

The power of a fan is defined as:
P2= Fan drive power
P1= Fan motor power consumption

Example: calculation of a fan with a motor efficiency of 70%



$$P_2 = \frac{V\ (m^3/s) \bullet Pt\ (Pa)}{\eta_{fan}} = 714\ \mathrm{W}$$

$$P_1 = \frac{V\ (m^3/s) \bullet Pt\ (Pa)}{\eta_{fan} \bullet \eta_{mot}} = 1021\ \mathrm{W}$$

The motor power consumption P1 is decisive for calculating the incurred energy costs.
Many manufacturers specify the fan drive power P2 for fans with a motor and separate blades, and therefore imply that there is less energy consumption.
However, the power consumption P1 is decisive for energy consumption and is approx. 30 % greater due to the efficiency losses in the motor.

Only the total motor power consumption of all fans (P1) is taken into account when the economic viability of fans in condensers or drycoolers is under consideration.
When the economic viability of fans in air coolers is under consideration, please also consider the fact that the total power consumption P1 is given off into the refrigeration room as heat load. This load must also be removed by the refrigerating system. This results in additional energy costs for the refrigerating system, depending on the COP value.

6. *Summary of part 1*

Energy-saving fans have profiled blades, extremely efficient motors and low flow losses due to the large fan diameter and the slow speed.
Güntner equipment complies with these criteria.

Apart from a few exceptions, the fans that we use have
-profiled crescent-shaped blades or high-tech blades
-efficient motors
-large fan diameter with slow speed for low flow losses in the fan

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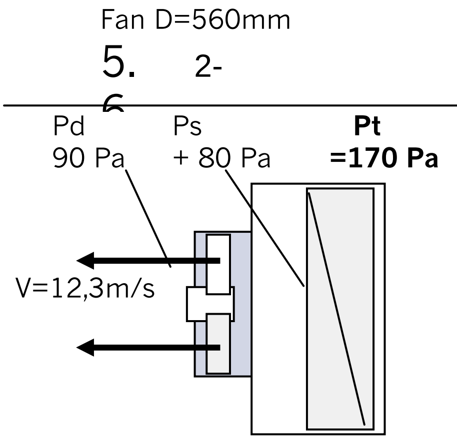
7. *Energy cost optimization*

7.1 *By means of large fan diameter and slow speed*

Various fans can be used to provide the delivery quantity that is required at low to medium pressures:
- Variant 1: Small diameter, fast speed
- Variant 2: Large diameter, low speed

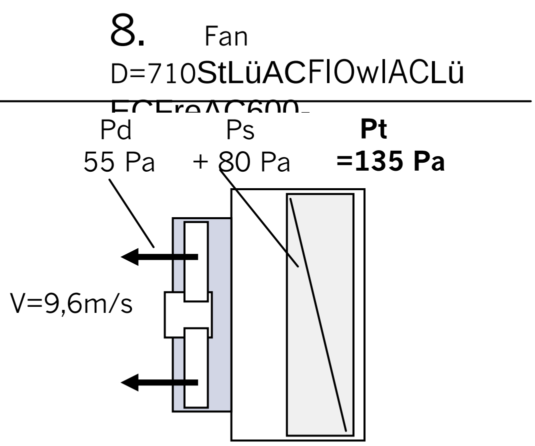
Variant 2 is basically preferred due to the low dynamic pressure loss (unusable pressure).

Example: Variant 1 *Variant 2*



$$P_1 = \frac{V\,(m^3/s) \bullet Pt\,(Pa)}{\eta_{fan} \bullet \eta_{mot}}$$

$$P_1 = \frac{3{,}75 \bullet 170}{0{,}7 \bullet 0{,}7} = 1300W$$



$$P_1 = \frac{3{,}75 \bullet 135}{0{,}7 \bullet 0{,}7} = 1033W$$

Both fans have the same volume flow and the same pressure.
In this example the power consumption of the fan with the large diameter and low speed is approximately 25 % less.

Remark:
For air cooler fans the air throw distance of the fan is also a design criterion.
In this case its not always necessary to select fans with fast speed.
Its possible to use energy-optimised fans with low speed using the Güntner Streamer and still achieve long throw distances.

7.2 *By reducing the speed using a speed controller*

Reducing the speed reduces the drive power considerably.
The drive power reduces dramatically in relation to the speed.

$$P2 = P1 * \left(\frac{n2}{n1}\right)^3$$

P= Fan drive power

n1 = Full speed

n2 = Reduced speed

Example:

Fan Speed	Air Volume	Power	noise / sound
			dB
100%	100%	100%	0.0
95%	95%	86%	-1.1
90%	90%	73%	-2.3
75%	75%	42%	-6.2
50%	50%	13%	-15
25%	25%	1,6%	-30

The speed of the fan in condensers can be reduced at night and during the winter months.
With air coolers, the speed can often be reduced at weekends and overnight if not much is being stored in the refrigeration building.

7.3 *Technical comparison between different systems for reducing the speed*

The speed reduction creates proportionally greater heat loss in the motor and additional loss due to the controller. The power consumption of the motors during partial load operation is not reduced to the same extent as the drive power for the fan blades, but depends on the control system that is used.

The following systems can be used to reduce the speed:

Control system	Speed
1-Delta – star changeover	approx. 100/70 %
2-Dahlander changeover	approx. 100/50 %
3-Voltage control with transformer	approx. 10 -100 %
4-Voltage control with phase cut controller	approx. 10 -100 %
5-Frequency control with frequency converter and filter	approx. 10 -100 %
6-Speed-controlled EC motors	approx. 10 -100 %

Control systems 1-4 involve control by varying the voltage.
In control system 5 the frequency is varied.
In control system 6 the current is converted into direct current.
Please note that not all motors are suitable for all types of control.

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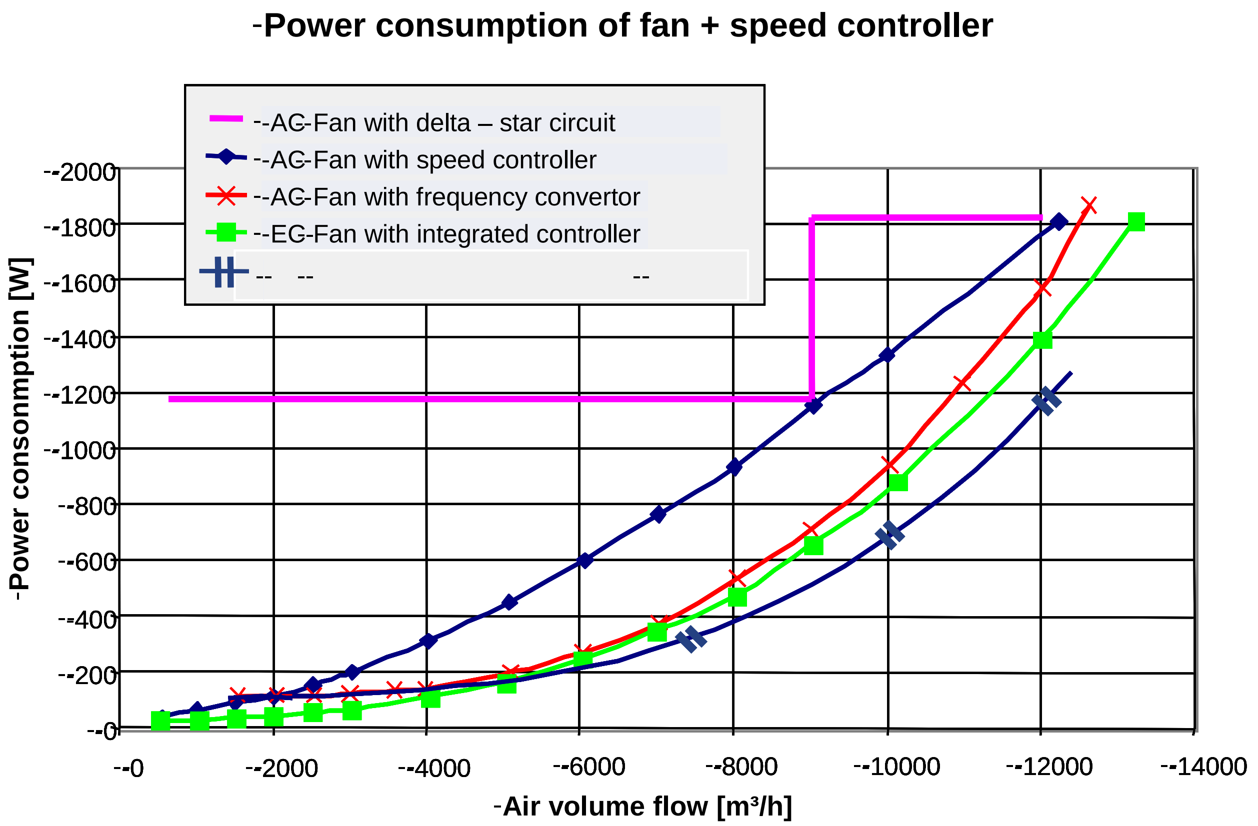
The diagram below shows the power consumption of the motors at reduced speed (air quantity) and with different control systems.



The greatest motor losses occur at reduced speed when using voltage control with a phase cut controller, a transformer or with delta / star switching.
Less loss occurs with the frequency converter with sine wave filter, which is also significantly more efficient in the reduced speed range.
The lowest engine losses and the highest efficiency at reduced motor speed are achieved with the fan with EC motor.

8. Summary

1. The most energy can be saved by specifically choosing Güntner equipment with slow-running fans. The additional costs are often less than those for more expensive fans and control systems, And pay for them selves within a short time by saving energy costs.

2. Energy consumption can be reduced significantly by reducing the speed with various control systems. The energy consumption of the fans can be optimised with frequency converters and sine wave filters (such as the Güntner sine wave controller) or fans with EC-motor.

3. EC fans have a motor efficiency that is approximately 10-15 % higher and an efficient control system. EC motors are technically comparable with AC motors and sine wave controllers, but have integrated controllers and involve less switch cabinet and wiring cost. EC fans are economical in equipment with fewer fans. Each fan can be used for several voltages but must be parameterised prior to installation.

4. Fans with owlet blades or other high-tech blades are more efficient by up to 15 % and have the best energy-saving potential in the upper speed range.

5. The energy consumption could be optimised even further by using fans with an EC motor and high-tech blades.

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