Paper ID: 149

Increasing efficiency of the conventional auxiliary systems of power plants (Reduction of Life Cycle Cost by operational excellence)

Thomas Schmager	Pasi Mannistö	Per Wikström
ABB Switzerland Ltd	ABB Switzerland Ltd	ABB Switzerland Ltd
Switzerland	Switzerland	Switzerland

Contents

1. Abstract

Booming demand for electricity, especially in the developing countries, has raised power generation technologies in the headlines. At the same time the discussion about causes of global warming has focused on emissions originating from power generation and on CO2 reduction technologies such as:

- alternative primary energy sources,
- capture and storage of CO_2,
- increasing the efficiency of converting primary energy content into electricity.

Concerning the third focus point, relatively little attention has been paid to the efficiency of auxiliary processes in thermal power plants, which account for about 5-8% of the gross generation capacity. Examples of auxiliary processes in thermal power plants:

- conveying and preparing the fuel
- moving the necessary air into the furnace
- moving the flue gases from the furnace
- returning the condensed water back to the steam generator
- maintaining the necessary cooling effect in the condenser and
- operating various emission cleaning processes.

A majority of these processes are run by centrifugal pumps, fans and compressors driven by large electrical motors.

This paper describes existing and proven possibilities to successfully control such processes while at the same time reducing the auxiliary power consumption in power plants by using modern electric variable speed drives. A detailed technical and economical analysis of an Induced Draft (ID) fan is provided. The paper describes how small investments can provide attractive methods to increase the net generation capacity and at the same time reduce emissions and fuel consumption.

2. Introduction

Rapid growth of electrical energy demand, not only in developing countries, discussions on fossil fuel reserves and the impact of thermal power generation on global warming, have increased the focus on alternative primary energy sources and the efficiency improvement techniques for the

conversion of the fossil fuels into electricity. Development efforts are ongoing to reduce, capture and/or store CO_2 emitted from burning fossil fuels.
The following is a quote from the McKinsey report of May 2007 “Curbing the energy demand growth”.
QUOTE
Reducing current losses from electricity generation and distribution is another substantial opportunity. Power generation used 155 QBTUs (Quad =10^{15}) – representing a hefty 37% of global energy use – to generate 57 QBTUs of deliverable electricity in 2003. In short, close to two-thirds of the energy put to the process is lost before it reaches the final end user.
UNQUOTE
In this essay, we will look at some of the auxiliary load in fossil-fueled power stations and see what can be done to reduce this part of the losses.

Thermal power stations use 3 to 8 % of their gross generation capacity for auxiliary processes. A conventional coal-fired thermal power plant uses slightly more (5 – 8%) of the electricity it produces for the auxiliary load. For a combined-cycle power plant, the auxiliary consumption can be less than 3.5 %.

Auxiliary processes are required to keep the generator running; they are, for instance, conveying fuel coal to coal mills and maintaining the cooling water flowing through the condenser. Most of the auxiliary power demand, up to 80%, is used by large electric motors that are typically connected to the medium voltage switchboard, supplied through auxiliary transformers. The increasing demand for “clean coal” and CO_2 emission capture and storage technologies will increase the auxiliary electricity consumption of electric power generation.

Power stations, especially base-load ones, are running at full load all the time. It is easy to imagine that not much change or control is needed for the auxiliary processes in such cases. The fact is however, that very few power stations run at their maximum capacity throughout the year; instead the capacity is being adjusted all the time to match demand and various operation conditions and parameters. See Figure 1 illustrating a one year capacity utilization curve and Figure 2 for the corresponding operating hours of a 660 MW steam generator.

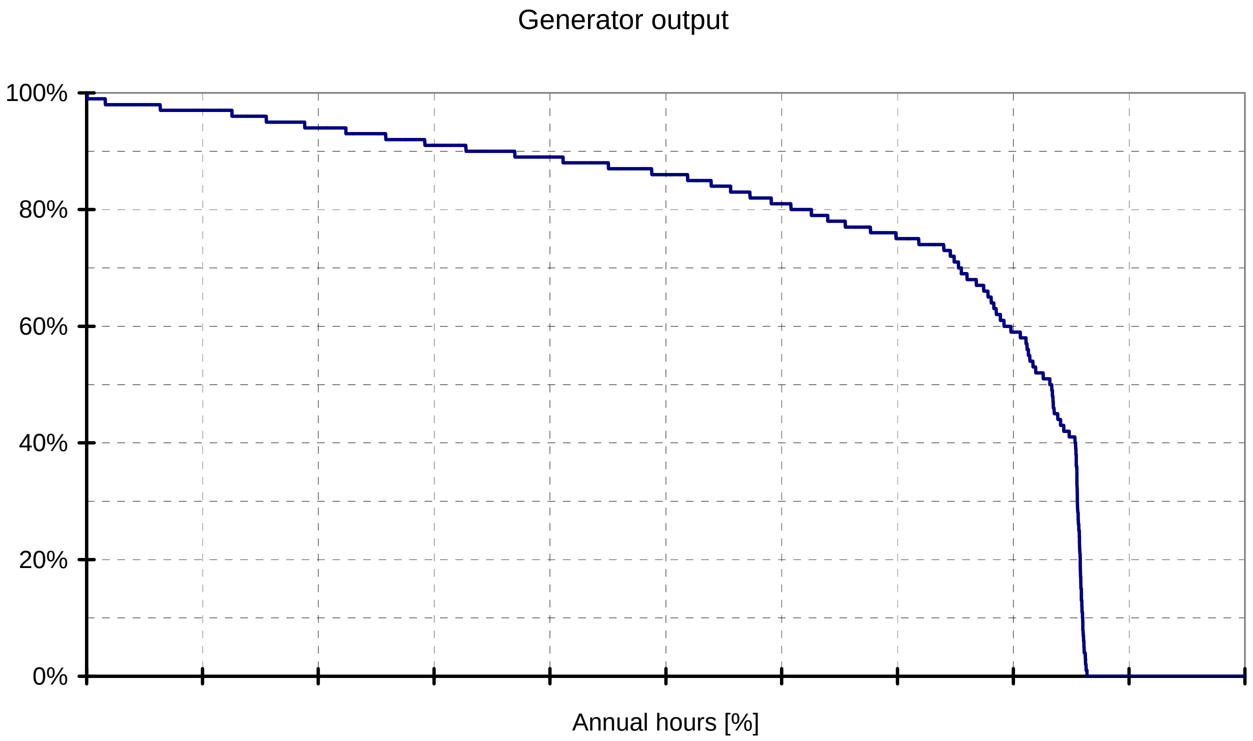

Figure 1: Capacity utilization curve of a 660 MW steam generator.

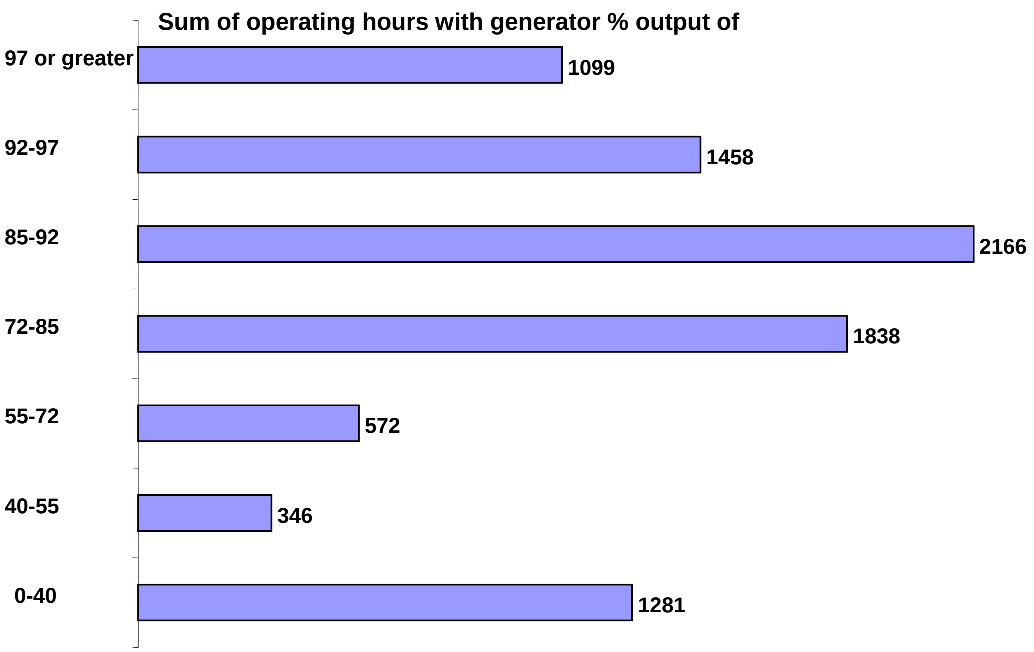

Figure 2: Operating hours at various load ranges of a 660 MW steam generator.

Auxiliary load machines, like centrifugal blowers, pumps or compressors, must be designed to operate reliably under all operating conditions, which leads to part load operation most of the time. This paper focuses on efficiency improvements of the plant's own electricity consumption. Variable speed control technology is being introduced as alternative to traditional mechanical control methods. The considerable economical benefits will be demonstrated in a case example.

The paper concludes that Variable Frequency Drives (VFDs) increase plant availability and flexibility through improved process control. VFDs reduce maintenance costs and improve heat rate by increasing the efficiency of auxiliary processes, which, in turn, reduces emissions. The improved heat rate and power output results in a higher profitability and faster return on investment.

3. Basics of fans

Fans are devices used to produce a gas flow. Centrifugal fan behaviour is characterized by the affinity laws, which are:
- flow is linearly proportional to the fan speed (if no counter-pressure)
- pressure changes with square of the ratio of speeds
- power demand (product of pressure and flow) changes with cubic of the ratio of speeds

3.1. Controlling the flow of fans

The gas flow is ducted to the process. The ductwork causes a pressure drop and defines the fan operating point, where the pressure generated by the fan and the pressure drop caused by the ducting and process are balanced (see Figure 3). Again, a change in the required gas pressure is proportional to the change in flow squared. Thus, the system effect is illustrated by a quadratic curve starting from the origin and crossing the head-capacity curve of the fan at the operating point. When the system pressure drop increases or decreases, the inclination of the system curve increases or decreases correspondingly.

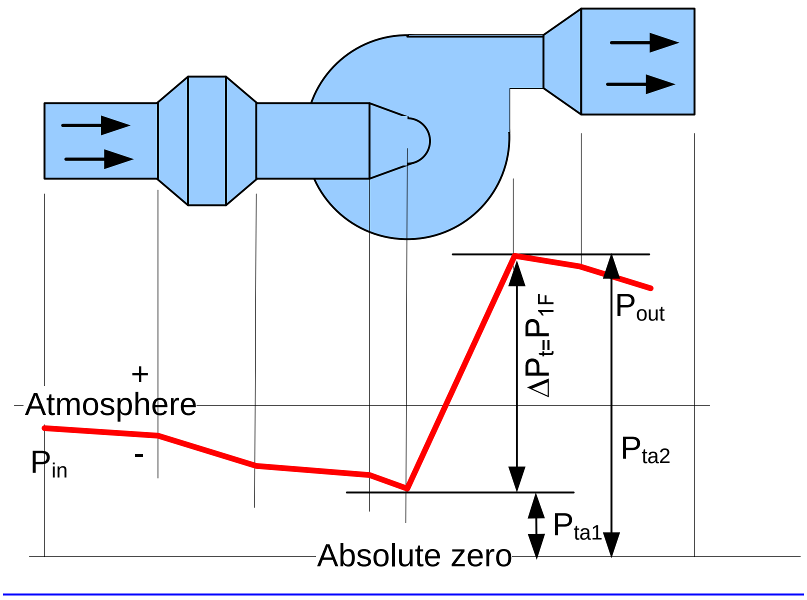

Figure 3: Pressure curve in a fan system.

The electrical power demand also depends on the following:

- efficiency of the fan,
- efficiency of the electrical motor.

It must be noted that the efficiency of the fan depends on the selected flow control technology, and some methods are clearly superior to others in this respect, as will be explained later in the paper.

The fan characteristic is illustrated with a diagram, head-capacity curve, showing the generated pressure as a function of flow; see the examples in Figure 4 for a fixed speed fan and in Figure 5 for a variable speed fan. From the curve it can be seen that a fan generates highest pressure at relatively low flow rate and that the generated pressure is reduced when the flow increases. The stable operation area is to the right of the maximum pressure point, the surge point. The equivalent efficiency curves are also indicated in the figures. It is obvious that the fan efficiency drops dramatically with reduced flow in Fig. 4, whereas it remains almost constant in Fig. 5.

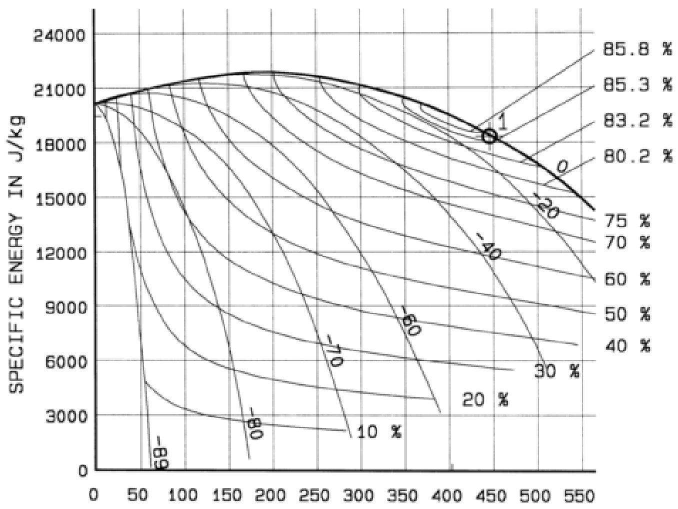

Figure 4: Fixed-speed fan graphs

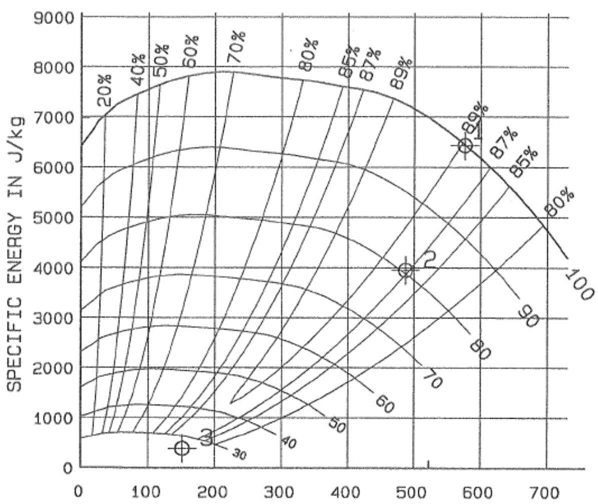

Figure 5: Variable speed fan graphs

The most commonly used fan types and the respective flow control methods are listed below and described in the following sections.

Constant speed fan

- Damper control (outlet or inlet)
- Guide vane control
- Fan blade pitch control (for axial flow fans)

Variable speed fan

- Mechanical drive system
- Electrical drive system

Figure 7 shows the comparison of the power demand versus volume flow for these control methods.

3.2. Constant speed fan

A fixed speed fan reaches its optimum efficiency at a certain pressure – flow point. The nominal operation condition of a fan, called Test Block (TB), is typically designed to be very near to such optimum operation point (ref. point “1” in Figure 4).

Each pair of two equal efficiency points on the fan curve are connected by an “isoefficiency” curve, an elliptic curve formed by all the points that have the same efficiency. In an ideal world the fan operating point would be located exactly at the efficiency optimum. In reality, the gas flow needs to be controlled, however, it leads to a complex situation with regard to optimization of the fan efficiency and the overall energy consumption. The gas flow control method has a big impact on the energy consumption. The other lines in Figure 4 (marked with “-20”, “-40”, “-60” etc.) refer to the closing position of the applied inlet damper control. The inlet damper control does not change the system curve, but moves the fan curve by reducing the available flow.

It must be noted from Figure 4 that the efficiency of a fixed speed centrifugal fan is always reduced when flow control is applied, i.e. the operation point is moved away from the point of the optimum efficiency. The gas flow within steam generators in power plants does always vary and the fans need to be operated away from the optimum efficiency point due to the following reasons:

- the fans are initially designed with a certain overcapacity
- the operating conditions vary
- the loading conditions constantly vary

Outlet damper control (see Figure 6 for details)

With this method, the airflow is regulated by means of an outlet damper or other system resistance. The fan is operated continuously at constant speed and the damper setting determines the flow. This is the least efficient means of control because the system resistance is increased to reduce the flow. In other words, the point of operation moves up on the fan curve as the dampers are closed.

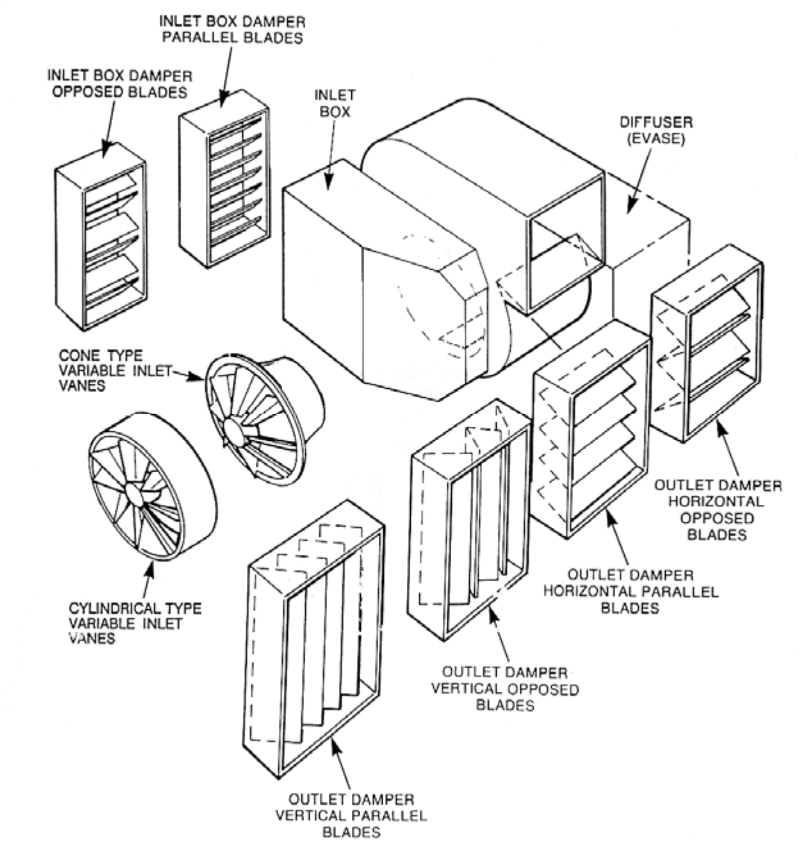

Figure 6: Physical arrangement of various flow control devices for a fixed speed centrifugal fan

Inlet damper control (see Figure 6 for details)

Flow control is achieved when the fan with inlet dampers is operated at constant speed, by varying the position of parallel dampers. There are some power savings associated with the partial closure because of the pre-rotation of the incoming air stream when the damper opens in the same direction as the fan rotation.

Variable inlet vane control (see Figure 6 for details)

The fan operates at constant speed and with variable inlet vanes. Fan flow is controlled by varying the pitch of the adjustable inlet vanes at the fan inlet. Fans with inlet vane controls, when operated with partially closed vanes, provide reduced power consumption due to the pre-rotation of the entering air or gas stream, when the inlet vanes open in the same direction as the fan rotation. The power consumption of the fan with inlet vane control is higher than that with variable speed control at reduced flow rates due to the throttling action as shown in Figure 7.

Fan blade pitch control

The angle of attack of the fan blades can be adjusted to vary the flow of axial fans. Blade pitch can be adjusted either on the fly or manually when the fan is stopped. Fans equipped with pitch adjustment on the fly are efficient within a certain range, but are characterized by relatively high maintenance costs. This control method is only applicable to axial fans.

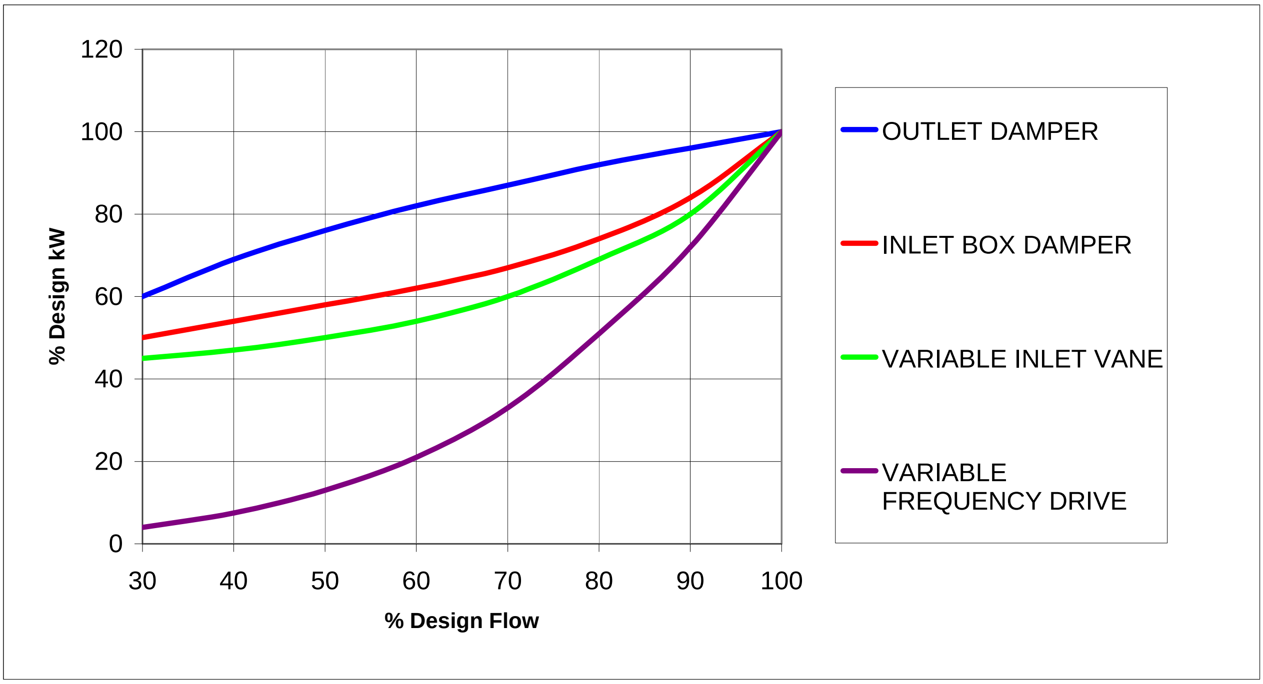

Figure 7: Power demand for different methods of flow control for radial fans

3.3. Variable speed fan

A variable speed fan has "zooming" capability; the head capacity curve moves up or down maintaining its shape when the speed is changed. Again, the efficiency reaches its optimum at a certain pressure – flow point for each speed, similar to a fixed speed fan, but since the speed can be varied, the best efficiency point can also be moved. As the change in the required gas pressure is proportional to the change in flow squared, each pair of two equal efficiency points on a variable speed fan curve will form quadratic-shaped curves approximately following the shape of the system curve (Figure 5).

This means that a variable speed fan can continue operation close to its maximum efficiency over the entire control range. As can be seen from Figure 7, control of fan speed provides the highest efficiency fan system. Medium voltage drives are the most efficient devices for controlling the speed of large fan motors.

For instance, the two operating points in the variable speed fan curve in Figure 5 have the following characteristics according to the fan data sheet: Please refer to Table 1. The reduction in the power consumption between TB (Test Block) and MCR (Maximum Continuous Rating) is noticeable.

Table 1: Comparison of the operating points TB and MCR of a variable speed fan.

Point designation	"1"	"2"
Loading	Design (TB)	MCR
Efficiency [%]	88.8	87.2
Power at shaft [kW (%)]	3455 (100)	1856 (54)
Rotating speed [%]	100	80

4. Design and operation of large (variable speed) fans in power plants

An ID fan is used to suck away flue gases from the furnace of steam generators and to push them further through the stack into the atmosphere. The gas flow needs to be controlled in order to maintain ideal burning conditions inside the boiler. The ID fan also needs to generate a high enough pressure for the gas stream, in order to overcome the counter pressures of air pre-heater, electrostatic precipitator, FGD (Flue Gas Desulphurization) plant and the stack. Please refer to the principle in Figure 3.

Due to environmental regulations, a growing amount of FGD plants is being installed in power stations with a remaining life time beyond 2012-2016. The addition of the FGD system usually means that the existing ID fan output must increase to handle the additional pressure drop of the FGD system. This will often necessitate a modification or a replacement of the ID fan. Many FGD applications require drive motors up to or over 10,000 kW and hence an efficient system to start, drive and control the fan is required.

The following are examples of varying operating conditions:
- fuel quality and moisture (e.g. the recently introduced popular bio-fuelled or RDF (Refuse Derived Fuel) boilers
- ambient temperature
- function of environmental control process (DE-NOx, DE-SOx, precipitator)
- leakage, blockade

Most of the time fans are oversized to meet the TB condition. This is also true when the fan is selected for a FGD application, where there are TB and MCR conditions. The selection of margins between TB and MCR is usually done with pressure varying as the square of the flow rate.

For an illustration to how systems get oversized, please refer to ABB Review 2/2007 page 74

When fans are operated with conventional inlet damper and inlet vane control, the static efficiency of the fan at the MCR condition is typically in the range of 70 to 80% and some times even lower depending on the margin between the TB and MCR rating. This is approximately 10 to 20 percentage points below the peak efficiency of the fan, however, IEEE 958 mentions ratio between MCR and TB being as low as 60 to 75%. If a variable speed drive is used for control, an ID fan can be selected to operate at or close to the peak efficiency at TB and MCR. Please refer to Table 1. Even base loaded units will typically show significant power savings for fans driven by variable speed drives due to the initial over dimensioning.

5. Electrical operating conditions in power plants

A power station is a challenging operation environment for electrical equipment. It is characterized by high short-circuit capability, fluctuating voltage, supply interruptions due to high-speed bus transfers, and very high availability requirements despite the prevailing conditions.
The operating conditions in power stations concerning installations of electric variable speed drives can be found in many standards. The following gives a short overview of the main requirements in selected countries:

5.1. Comparison of operational conditions

Normally, standards define conditions like supply voltage levels and variation, both long-term and short-term dips and even interruptions.

Table 2: Comparison of basic electrical operating environment in power plants, various sources

Phenomena	unit	KEMA S-17 part 4 (Sep) Oct 1988	A Danish project	SDRC (Chinese) Industry[2004] 872 - draft
Full output under supply voltage variation	%	+10/-15	+/-10	+/- 15
Operation under over-/under-voltage	%	+10/-30	+30 /-20	
Interruption	ms	“few seconds”	300	3000
Frequency variations	%	- 5	+/-2	+/- 5

Today’s electric variable speed drives are or can specifically be designed to perform during the strictest requirements mentioned in above table. Most electric variable speed drives can perform either a power-loss-ride-through over short supply voltage interruptions up to a few seconds, or a flying start after the voltage has resumed.

6. Economical benefits calculation for electrical drive systems

As shown in Figure 7, the most efficient way to control the speed of a fan is by using an electric variable speed drive system. With the power consumption varying as the cube of the speed, considerable savings in power consumption are achieved when the fan is operated at lower speeds.

Large Induced Draft (ID) fans are perfect candidates for medium voltage AC drive technology, where the energy savings can pay back the cost of the variable speed drives in a few years, or can be used to help finance the overall project.

From a power stations' total efficiency point of view the control technology of the auxiliary loads is an important factor. The control method chosen (poor vs state-of-the-art technology) can make a difference of up to 60% or more of the fan efficiency; as has been noticed in process industry [4].

From Figure 2 can be seen that even the loading of a large steam generator varies considerably. An economically interesting question is: "How efficiently does the existing, or planned control technology work." To make an economical analysis on it, the key task is to calculate how much power is needed to move the gas, of which the process values (temperature, density, pressure variations and flow) are known. With the gas-moving power, the fan characteristic curve, the flow, the pressure and efficiency, it is possible to calculate the mechanical power at the fan shaft over the operating range. If detailed fan data or curves are not available, the actual energy consumption of the driver motor could be taken out from the trend library of a DCS (Distributed Control System). Models for economical evaluation are available in literature; for instance the sample in [1] suggests the following three bands represent the load projections of a fan:

a) 25% of the time the fan is off line
b) 25% of the time the fan operates at 50% of the fan test block (TB)
c) 50% of the time the fan operates at 75% of TB

The steam generator annual loading, illustrated in Figure 1, is used in this example. The annual hours were grouped into the indicated load projections in Figure 2.

In order to apply a general calculation method for a case where the exact fan curve is not available, the fan curve in Figure 4 could be used for the steam generator, by unifying the flow and pressure axes. It is assumed that the flow control methods are the same.

Key in analyzing the power consumption of a fixed speed fan with the flow controlled mechanically by an inlet damper, and a variable speed fan, is to calculate the power consumption in each of the selected operating points. In this case the flow at the TB is 610 m^3/s and the pressure 656 mmca (mm water column). Using a gas density of 0.829 kg/m^3 and the fan peak efficiency of 85.8%

indicated on the graph, we get P_{TB} = 3’791 kW. The steam generator in question has two identical ID fans in parallel, so the total power consumption per steam generator is twice this amount.

The power consumption at TB does not really help since the required gas flow through steam generator is remarkably less than at TB, as was previously mentioned. If we assume the flow at 100% generator output being 90% of the TB, which may not even fulfill some of the most conservative design margins, we can calculate the corresponding flow for each of the selected generator load points. With these flow values, and the pressures and efficiencies read from the normalized fan curve, the powers can be drawn for the fixed speed fan (damper control), see Figure 8.

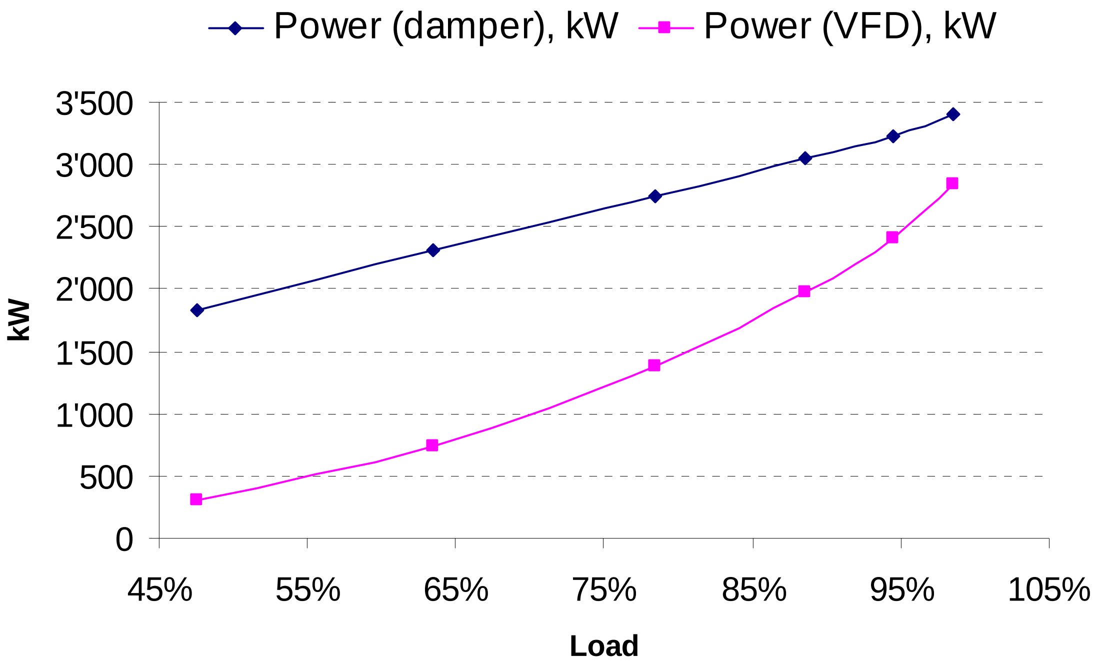

Figure 8: Power consumption curves of fixed-speed (damper control) and speed controlled (VFD) ID fan

The losses (in % of the actual load) of a VFD system increase only marginally at part load. The powers for the compared variable speed fan are simply calculated from the cubic power demand of a fan taking into account the typical 3-5% losses of a VFD system at nominal load. The values can easily be handled in a spreadsheet calculation, which for instance could look like in Table 3 below.

Table 3: Example calculation spreadsheet

Load point	48%	64%	79%	89%	95%	99%	TB
Hours	346	572	1838	2166	1458	1099	
Density							0.829
Flow [% of TB]	43	57	71	80	85	90	100
Flow [m3/sec]	261	349	431	486	519	541	610
Pressure [mmca]							656
Fan efficiency [%]	18	27	32	40	55	70	85.8
Fan power, damper [%]	48	61	73	81	85	90	100
Power [kW], (vanes)	1'825	2'305	2'753	3'053	3'233	3'397	3'791
VFD efficiency [%]	95	96	97	97	97	97	97
Power [kW], (VFD)	313	740	1'386	1'977	2'407	2'849	3'909

From the data in Table 3, the yearly energy consumption is calculated by multiplying the hours of operation for each loadpoint with the corresponding power requirement. Figure 9 shows the result of a comparison of energy consumption between a fixed speed and variable speed fan, when electricity is valued at EUR 45 / MWh. It can be seen that the variable speed fan generates savings in all the generator's normal operating points, even at the nominal load. This is due to the fact that the equipment is over-dimensioned, and the operation at part load with mechanical control technologies is inefficient.

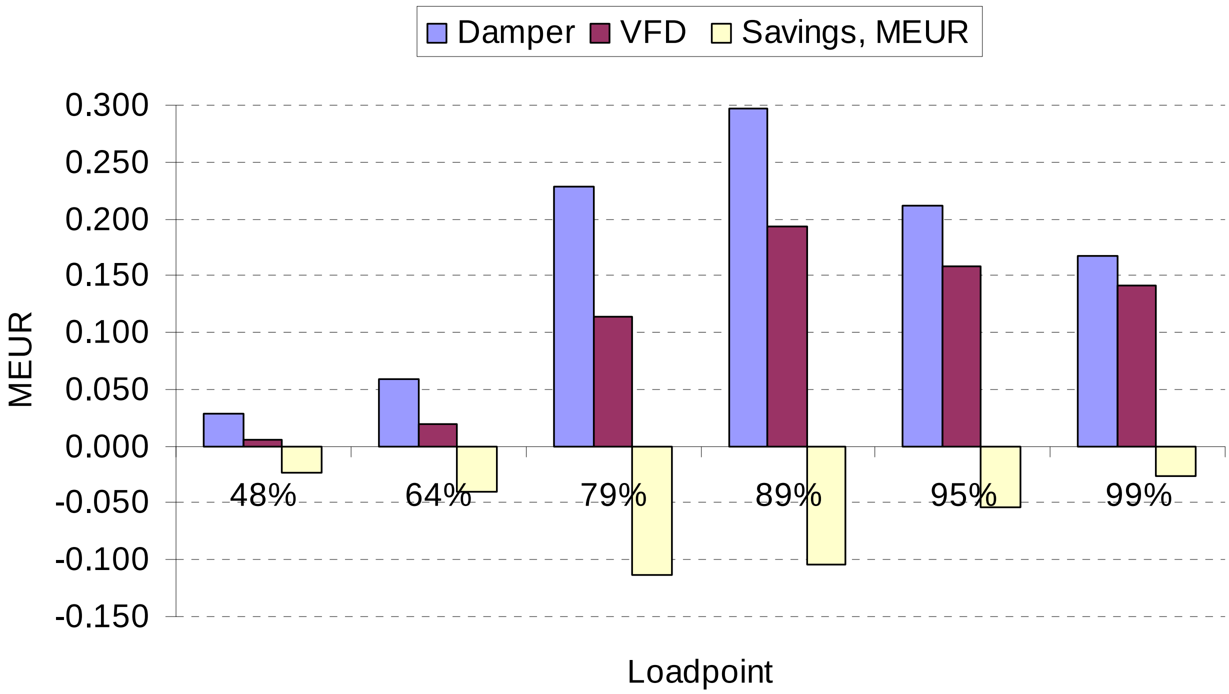

Figure 9: Distribution of power consumptions of fixed speed and variable speed ID fan at the annual operation points.

Using some typical equipment prices of a suitable VFD system, the following investment pay-back chart can be created,

Figure 10:

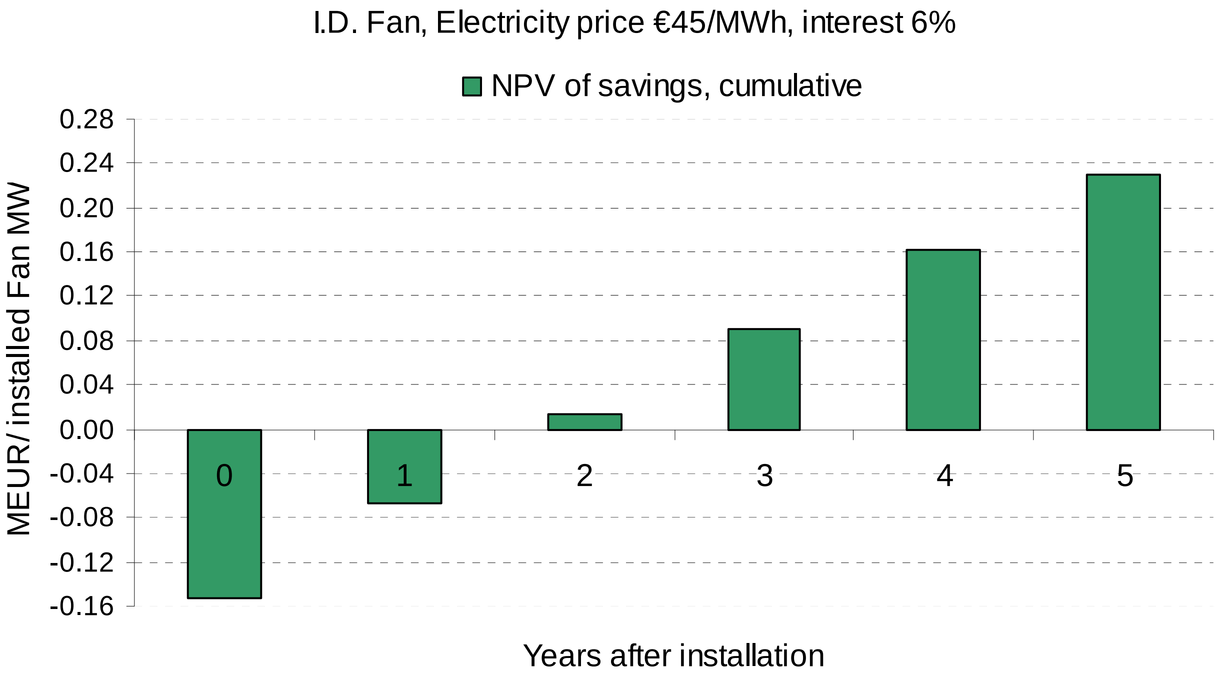

Figure 10: Annual energy saving benefits compared with initial net investment of a variable speed drive system

The figures in the year of installation can be divided in two parts, depending on the actual situation; the "net VFD investment" is the additional necessary investment of a VFD system, while the "NPV savings" in the year "zero" means the alternative investment, like a new, larger fixed speed motor. In the latter case the fan would be upgraded and a motor with bigger capacity would be required. It must be noted that the above calculation is applicable for one of the two installed fans.

In this illustrated case, it can be concluded that the pay-back period of a VFD system for controlling an ID fan becomes less than 2 years and this without considering any reduction in maintenance costs. Such additional savings can be treated similarly to the savings in the annual energy costs.

In the above case the steam generator was operated most of the time between 72 and 92 % of the 660 MW generator's output (refer to Figure 2). In Table 3 can be seen that the power consumption is 1 – 1.4 MW less in each of the two ID fans, which represents almost 0.4% of the generator's nominal output.

Similarly, at the 79% load (521MW), the 'saved' 2 x 1.4 MW means actually more than 0.5% improved plant efficiency. The additional 2 x 1.4 MW also contribute to the production increase through an increased number of operating hours. The plant becomes more competitive at partial load.

The variable speed fan control can be considered as a simple and inexpensive way to increase the power of the power plant. There are no additional operation or fuel costs and no CO_2 emissions. It has a positive effect on the plant controllability and due to the smooth starting capability it reduces mechanical maintenance and extends equipment lifetime.

7. Advantages of variable speed fans driven by medium voltage AC drives

Variable speed fans driven by medium voltage AC drives have the following advantages over conventional inlet vane or inlet damper controlled fans:

7.1. Energy efficiency

The outstanding efficiency of variable speed fans has been discussed in this paper. The fan input power varies as the cube of the speed and while satisfying the system requirements at maximum continuous rating or at lower loads, power savings are maximized as compared to any other method of flow control. Sometimes it is difficult to match all three parameters (flow, pressure and speed) at the maximum efficiency point. To select a fan at maximum efficiency, sometimes the fan needs to be selected at a speed other than synchronous speed, which becomes possible with a variable speed drive. Also, a fan has higher efficiency when inlet vanes or inlet dampers are totally eliminated. Through the energy efficiency of variable speed fan, investment in electric variable speed drives can typically prove to be the most economical choice in all cases with longer than few years operating period. This is especially the situation in cases where investment must be split over several years and the alternative is to install and operate a heavily throttled fixed speed fan dimensioned to future demand.

7.2. Reliability, controllability, operability

Faster and better control together with an increased control range are major reasons for considering variable speed drive control.

Controllability – This is a major advantage over any damper or vane controlled fans. Flow varies directly proportional to speed and pressure varies with the square of the speed. Additionally, the system resistance (pressure drop) varies with the square of the flow. The superior control of these parameters, flow and pressure, is achieved by adjusting the speed of the fan with an electric variable speed drive. With inlet vanes or inlet dampers the control is not as precise.

The reliability of the system is greatly increased because there are no other moving parts in the system.

Power-Loss-Ride-Through – Some medium voltage AC drives have the ability to ride-through prolonged voltage fluctuations (e.g. transient voltage dips) on the supply network without tripping. This feature is an advantage compared to DOL (Direct-On-Line) motors, which will trip in a shorter period of time. This feature, together with “Flying Start” (when a drive can catch a spinning fan – for example after an extended loss of supply) results in a fan drive system, which is robust towards fluctuations in the supply network, refer to Table 2.

Lower noise – Due to the fact that dampers are eliminated in the fan for flow control and the elimination of throttling action, the noise level is considerably lower. This usually amounts to 8 to 10 dBA noise reduction.

Furnace implosion may be a concern in power plants, meaning the ID fan could cause the boiler to collapse due to too much under-pressure in the furnace. The implosion may occur as a result of a control malfunction or through operator error, for instance the dampers on the FD fan are closed while the ID fan is in operation.

Risk of furnace implosion can be reduced with variable speed fan control, because of the following known operational characteristics.
First, as learned, a variable speed fan operating at MCR has considerably lower speed than the design speed (TB) of the corresponding fixed speed fan. This means lower pressure, and lower risk of implosion, at zero flow.
Secondly, a variable speed fan can be controlled to reduce speed immediately upon detection of a dangerous situation. The operation point will thus route towards zero head of the head capacity curve, unlike the situation of a fixed speed fan, which has the characteristic of increased pressure with declining flow. Further, an electrical variable speed control will be actively controlled during the ‘emergency’ speed reduction. A fixed speed fan motor will slowly coast down towards zero speed when the circuit breaker is opened, and depending on the system design, it may not be possible to re-start the motor directly across the line, as long as speed of the rotating inertia has decreased under a defined minimum starting speed.

7.3. Soft starting capability

There is no motor inrush current (which typically can be 650% of the full load current), which means less wear and tear and increased lifetime of the motor, coupling and fan. Additionally, the impact on the supply network is greatly reduced, meaning less likelihood of causing problematic voltage drops during starting. The inherent feature of the variable speed drive makes it possible to nullify the effects of inertia and the rate of acceleration of the system can be adjusted or programmed.

7.4. Reduced maintenance

Inlet vane or damper control usually requires some periodic maintenance and elimination of inlet vane controls reduces maintenance costs.

As the speed is reduced, the peripheral velocity of the fan rotor is reduced and, as a result, impingement and sliding velocity of the particles in the gas is greatly reduced compared to constant speed fans. This increases the fan lifetime and reduces maintenance.

Large ID fans equipped with inlet dampers at certain damper settings can cause a rotating stall. This can result in ductwork vibrations of very high magnitude, which forces the user not to operate the fan at the onset of stall or below. Inlet vane controls can cause cone vortex problems because of too much swirl and can cause ductwork pulsations in the discharge side ductwork. Speed control of the fan eliminates the use of damper or vane control and, thus, the pulsation problems are avoided [2].

7.5. Reduced investment in other parts of plant

Because of the soft start capabilities, a less expensive motor having lower inertia capabilities can be utilized (as long as there is no drive by-pass requirement). When the motor power can be reduced, savings can also be achieved in the electrical distribution system, as voltage drop due to direct on line starting is no longer an issue. The distribution system can have a lower fault level. .

Variable frequency drives offer the possibility to rotate the fan at a lower speed to avoid thermal stratification, thereby eliminating the need for a turning gear.

Ability to start a hot gas fan at ambient conditions at slow speed – Though power consumption varies directly with the density of gas, with speed control, power consumption varies as cube of the speed. As such, a variable speed fan makes it possible to operate a hot gas fan at ambient conditions at lower speed, and eliminates the need for a two-speed motor or a larger motor.

8. Medium voltage AC drives

Medium voltage AC drives

Medium voltage AC drives are available in a variety of arrangements, depending on whether the motor to be controlled is asynchronous or synchronous. For example, asynchronous motors (such as cage induction motors) are typically controlled by Voltage Source Inverters (VSIs). Synchronous motors for fan applications are typically controlled by Load Commutated Inverters (LCI).

Voltage source inverter

Today, state-of-the-art medium voltage AC drives (as shown in Figure 11) combine the VSI technology with efficient power semiconductors, excellent motor control software and a sine wave output. These technologies combined with a standard cage induction motor form an ideal electric drive system with the following advantages:

- Operates on a standard, robust, low maintenance cage induction motor
- Retrofits onto existing motors possible. Fixed speed fans can be converted to variable speed (after having checked with the fan manufacturer)
- High drive system efficiency
- Low network harmonics
- High power factor (close to unity)
- Elimination of variable speed drive induced torque pulsations
- Small footprint (an advantage for retrofits)
- Quieter motor operation

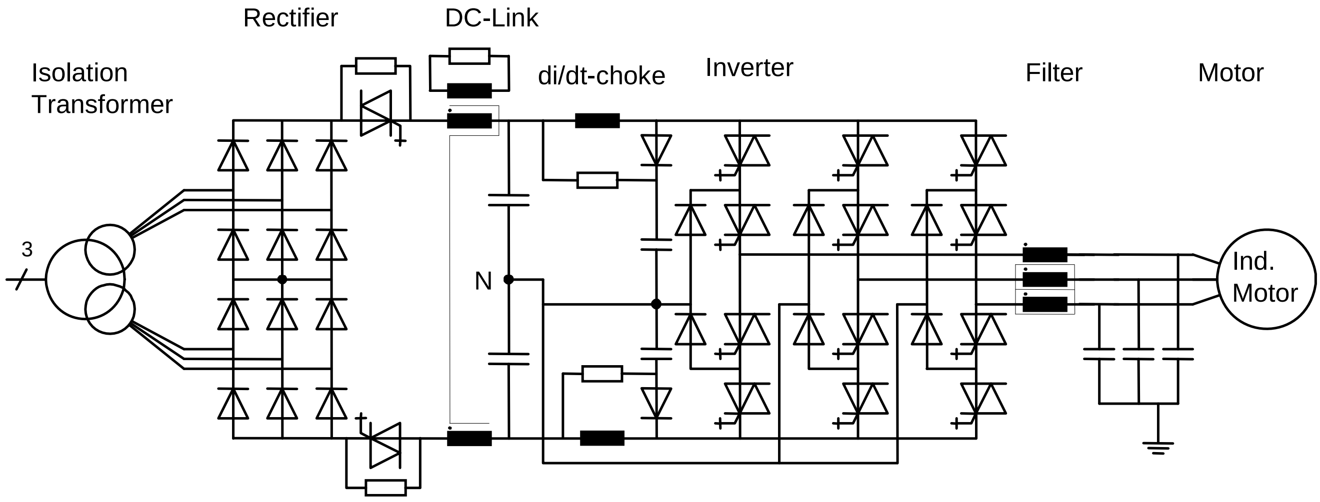

Figure 11: MV AC drive using the VSI topology, IGCT power semiconductors and sine wave output filter

9. Summary

- ***Operating point effects fan efficiency***
- ***Fans are usually over dimensioned***
- ***There is always need to control***
- ***Summary of the main benefits of large variable speed ID fans driven by medium voltage AC drives:***

Feature:	**Benefit:**
High efficiency	• Reduced energy costs
Soft starting	• Reduced stress on fan, motor and coupling, resulting in extended equipment lifetime • Reduced maintenance costs • Reduced impact on the electrical supply network (no voltage drop due to starting) • Elimination of problems with starting high inertia loads • Programmable acceleration ramps and profiles • Unlimited number of starts per hour • Reduced cost. (motors do not need to

	be sized for high inertia capability
High reliability and availability	• Reduce downtime • Improved process availability
Lower audible noise	• Improved working environment
Low fan erosion at lower speeds	• Extended fan lifetime • Reduced maintenance costs
Flexible motor speed	• A fan with other speed than defined by motor at 50 or 60 Hz can be selected • Flexibility in operation
Elimination of pressure pulsations	• Reduced ductwork vibration and fatigue • Lower noise
Elimination of inlet vanes and dampers	• Reduced maintenance costs
Ability to rotate fan at lower speed	• Eliminates the need for a turning gear
Ability to start a hot gas fan at ambient conditions at low speed	• Eliminates the need for a two-speed motor or a larger motor
Precise flow control	• Improved controllability • Improved process stability
Wide speed control range	• Flexibility in operation
Power-Loss-Ride-Through	• Increased process availability due to reduced number of trips

About ABB MV Drives: ABB's research into AC drives technology started in the 1960s. This long history in the AC drives business has brought the company vast experience in AC drives technology as well as application know-how in a wide range of industries, including the Utility Industry. ABB is the world's largest drives manufacturer, and is the world leader in medium voltage AC drives.
About ABB: ABB has ISO9001 certified manufacturing facilities, stringent quality inspection requirements and an integrated project management team approach to ensure quality products delivered on time to meet client expectations.

References:

[1] IEEE Std 958-2003 - IEEE GUIDE FOR THE APPLICATION OF AC ADJUSTABLE-SPEED DRIVES

[2] Varanasi, et al. : SCR Retrofits Provide Opportunity For Variable Speed Fans, Power Engineering November, 2000

[3] Hiroaki Yamada et. Al.: High-voltage Direct Inverter Applied to Induced Draft Fan Motor at Takehara Thermal Power Station No. 3 of Electric Power Development Co., Ltd. 2004.

[4] Nathan Schachter, CIMENTEC Engineering Ltd: Energy Efficient Speed Control Using Modern Variable Frequency Drives