

ABB drives in power generation  
Medium voltage drives for more efficient  
and reliable plant operation



# ABB – a world leader in the supply of variable speed drives for the power generation industry

## Variable speed drives improve the heat rate and net power output of power plants and reduce operating costs.

### Efficient plant operation

Today, power producers operate in a highly competitive marketplace. Business pressure from market liberalization and rising fuel costs require every producer to look for the most effective ways to convert a bigger share of fuel's energy into salable kilowatt hours (kWh). Improving the heat rate of power plants is becoming increasingly important.

A thermal power plant usually consumes 5 – 10 percent of the electricity it produces. Due to the installation of anti-pollution devices this share has been increasing in recent years.

Processes driven by electric motors typically consume 80 percent of this electricity. Implementing electric variable speed drives (VSDs) improves the heat rate by increasing the efficiency of these processes.

Operational flexibility is the key to cost-efficient production during low and peak demand. An improved heat rate and power output result in higher profitability and fast return on investment.

The investment in variable speed drives increases plant availability and flexibility through improved process control and reduces emissions and maintenance costs.

### Variable speed drives

ABB supplies drive products and systems for various kinds of processes and applications in the power generation industry	
Gas turbine (GT) power plants	GT starters, drives for fuel gas booster compressors, boiler (HRSG) feed-water pumps and cooling water pumps
Steam generating boilers, waste incinerators	Drives for boiler feed-water pumps, cooling water pumps, circulation water pumps, forced draft (FD) and induced draft (ID) fans
District heating, combined heat and power	Drives for water circulation pumps in industrial and municipal combined heat and power (CHP) plants
Fuel handling	Drives for conveyors and coal mills
Selective catalytic reduction, flue gas desulphurization	Drives for ID booster fans, limestone slurry feed pumps and absorbent circulation pumps and oxidation air compressors
Pumped storage hydro power plants	Soft starters for hydro turbines
Renewable energy	Drives for solar thermal power plants, geothermal power plants and soft starters for synchronous condensers
Nuclear power plants	Drives for feed-water pumps, condensate recirculation pumps and cooling water pumps

# Benefits of variable speed drives

Motors, controlled by variable speed drives, consume significantly less energy than fixed-speed motors.

## Flow and pressure control

Air and water consumption vary greatly during a day. As such, continuous control of the processes and equipment, such as fans and pumps, is required.

## Mechanical versus electrical control

Processes driven by pumps or fans are usually controlled either mechanically with inlet guide vanes, throttling valves or hydraulic couplings, or electrically with variable speed drives.

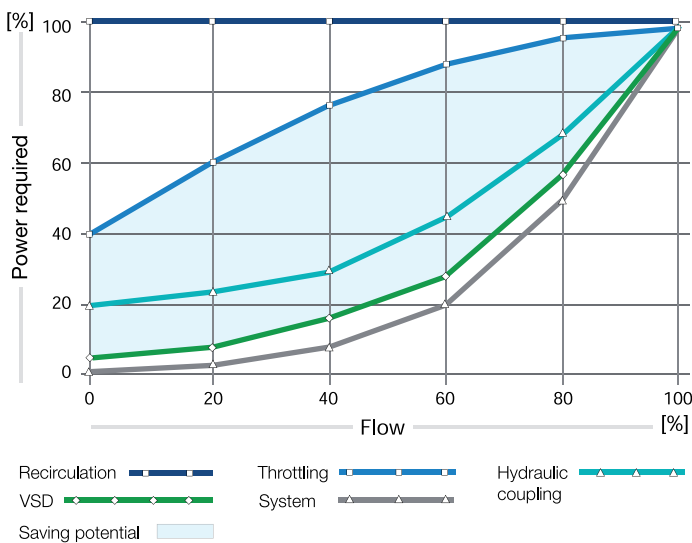
With mechanical fixed-speed solutions, it is impossible to achieve the optimal process efficiency over the whole control range.

With electric variable speed drives, changing the production volume is simply achieved by changing the motor speed. This saves energy, decreases CO<sub>2</sub> emissions and minimizes the total operating costs. Electric variable speed drives have the highest efficiency and are superior to hydraulic couplings and other mechanical control systems.

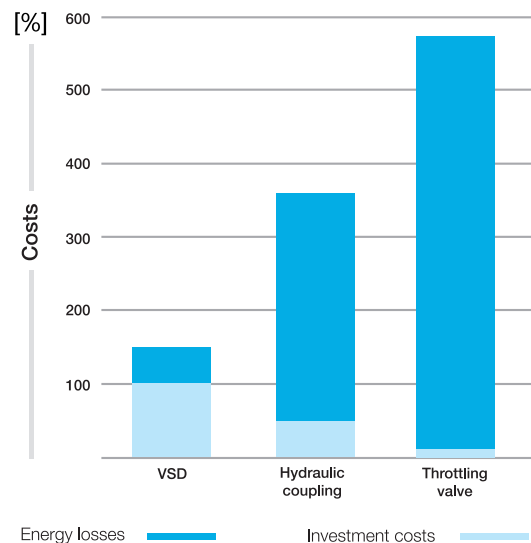
## Energy savings and reduced emissions

Since pumps and fans typically run at partial load, huge energy savings can be achieved by controlling their speed with variable speed drives. A small reduction in speed can make a big reduction in the energy consumption. A pump or a fan running at half speed may consume as little as one eighth of the energy compared to one running at full speed.

By employing variable speed drives on centrifugal pumps and fans, instead of throttling or damping, the energy bill can be reduced by as much as 50 percent. Consequently, electric variable speed drives also help to reduce NO<sub>x</sub> and CO<sub>2</sub> emissions.



Power consumption for various pump control methods



Comparison of investment costs and energy losses of different control methods.\*

\*Calculated for a 1,300 kW (1,740 hp) pump application, for three years operation

### Soft starting

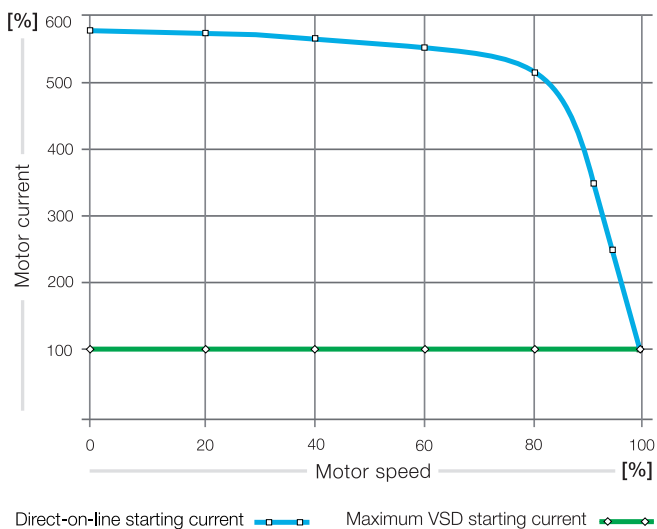
Accelerating rotating machinery with heavy load torque and/or high mass moment of inertia, such as ID fans, imposes large stress on the electrical supply network and on the mechanical parts of the shaft string. A direct-on-line started electric motor can cause starting currents of up to six times the nominal current. This will cause a voltage drop that is likely to disturb the process, especially if the supply network is weak.

Soft starting with variable speed drives results in considerable benefits:

- No process disturbance due to voltage drops; no trips of other electrical devices connected to the same bus
- No excessive thermal or mechanical stress on the motor, resulting in a longer lifetime
- Immediate start-up without warm-up delay (as required for steam turbines)
- Controlled and smooth start-up

### Benefits of drives

- High availability
- Fast and precise process control under all conditions
- Lower energy consumption
- Reduced emissions
- Soft starting capability for a longer lifetime of electrical and mechanical equipment



Motor current for various starting methods

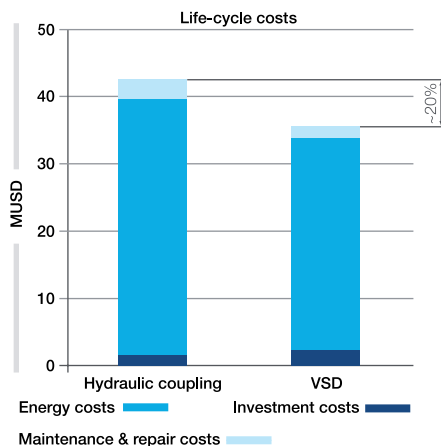
# Variable speed motor versus fixed speed motor with hydraulic coupling

For decades hydraulic couplings have been used in many processes to control the speed of fans and pumps. But the benefits offered by variable speed drives offer a compelling alternative worthy of consideration.

Comparison of ...	Hydraulic coupling	Electric variable speed drive
Efficiency	medium to low (varies with load)	high (over entire load range)
Cooling requirements	high	low
Initial investment costs	low	medium
Maintenance	high	low
Availability	medium to high	high
Total life-cycle costs	high	very low
Influence on supply network	none	minimal with suitable topology
Starting current from supply network	up to 600 percent of rated current	less than rated current
Dynamic response	low	high
Environmental influence	high oil volume hazard	none
Space requirement at motor	extended shaft length	none
Weight	very high	medium
Speed control range	limited	wide and easy to adjust
Mean time to repair	several days	few hours

A variable speed drive has a much higher efficiency than a hydraulic coupling, which considerably reduces the overall life-cycle costs. The high starting current of fixed speed motors can cause serious problems on weak power systems. The limited speed control range, the lack of super-synchronous speed operation, the poor dynamic response and higher maintenance costs are other points which limit the application of the hydraulic coupling.

Taking all these factors and the total life-cycle costs into consideration, an electric variable speed drive is the superior solution.



VSD vs. hydraulic coupling	
Break-even point	1.5 years
Net return on investment	900%
Net present value of savings	\$7,000,000
Life-cycle cost savings	20%

The calculation is based on the following data:  
 Power: 9 MW; service life: 15 years; cost per kWh: \$0.07;  
 operating time per year: 8,000 hours

# Variable speed drives for fans and pumps

Since fans and pumps typically run at partial load, huge energy savings can be achieved by controlling their speed with variable speed drives.

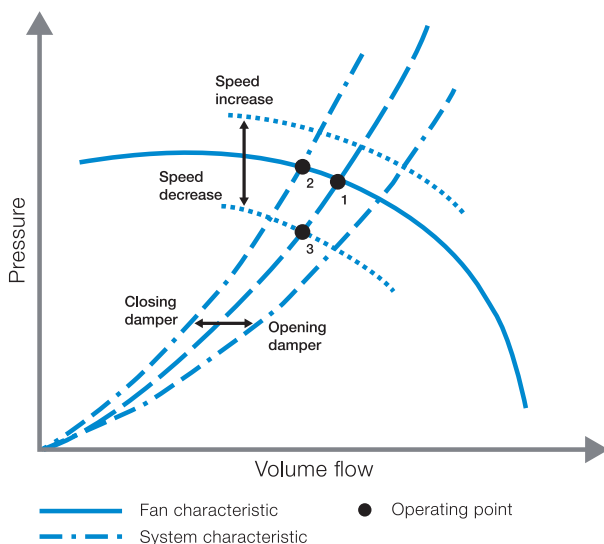
## Flue gas fans

The performance of centrifugal fans is controlled by a set of rules known as the affinity laws, which state that:

- flow is proportional to speed
- pressure is proportional to the square of the speed
- power is proportional to the cube of the speed

The diagram below shows a typical fan characteristic which is a function of pressure and volume flow. Also shown is a typical system characteristic; the operating point of the system is at the intersection of those two curves. If the required volume of air is deviating from this point, the fan or system characteristic needs to be changed.

Traditionally, the most common way of changing the operating point is by using a damper which alters the system characteristic (operating point moves from position 1 to 2, see Fig. 1) increasing the system losses. However, increasing or decreasing the fan speed with a variable speed drive will change the fan characteristic itself (point of operation moves from position 1 to 3, see Fig. 1) without adding additional losses. The energy consumption can be reduced significantly.



Typical fan characteristic showing operating point

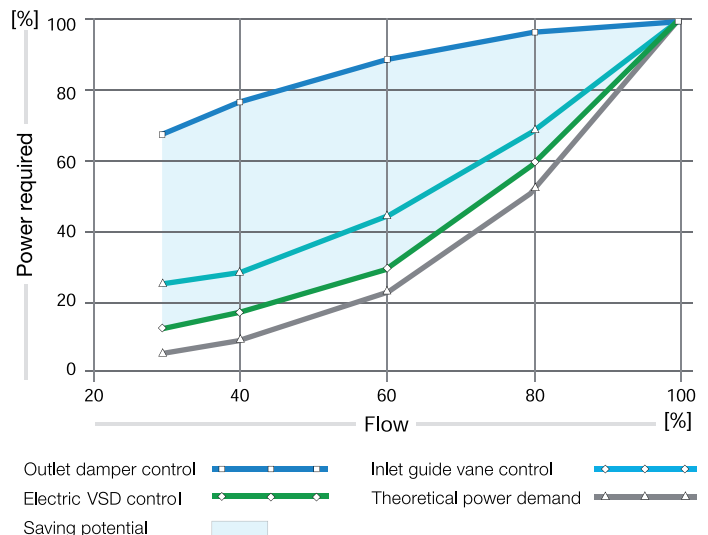
## Feed-water pumps

Feed-water pumps are characterized by high reliability requirements and fairly high dynamics during plant load changes. They normally make the biggest contribution to a plant's own energy consumption.

With today's variable speed drive technology those pumps can be controlled with best possible efficiency without compromising reliability. Furthermore, mechanical maintenance costs can be reduced by controlling the feed-water flow with variable speed drives instead of throttling valves or hydraulic couplings.

## Energy efficient control of fans and pumps

The control method employed has a major effect on the running costs. High control accuracy, excellent energy economy and reduced maintenance costs are achieved with variable speed drives for all fans and pumps in the power generation process, including primary air and flue gas fans, feed water, condensate, cooling water and district heating pumps.



Power consumption for various fan control methods

# Variable speed drives for power generation applications

Various processes and applications benefit from using variable speed drives.

## Pumps

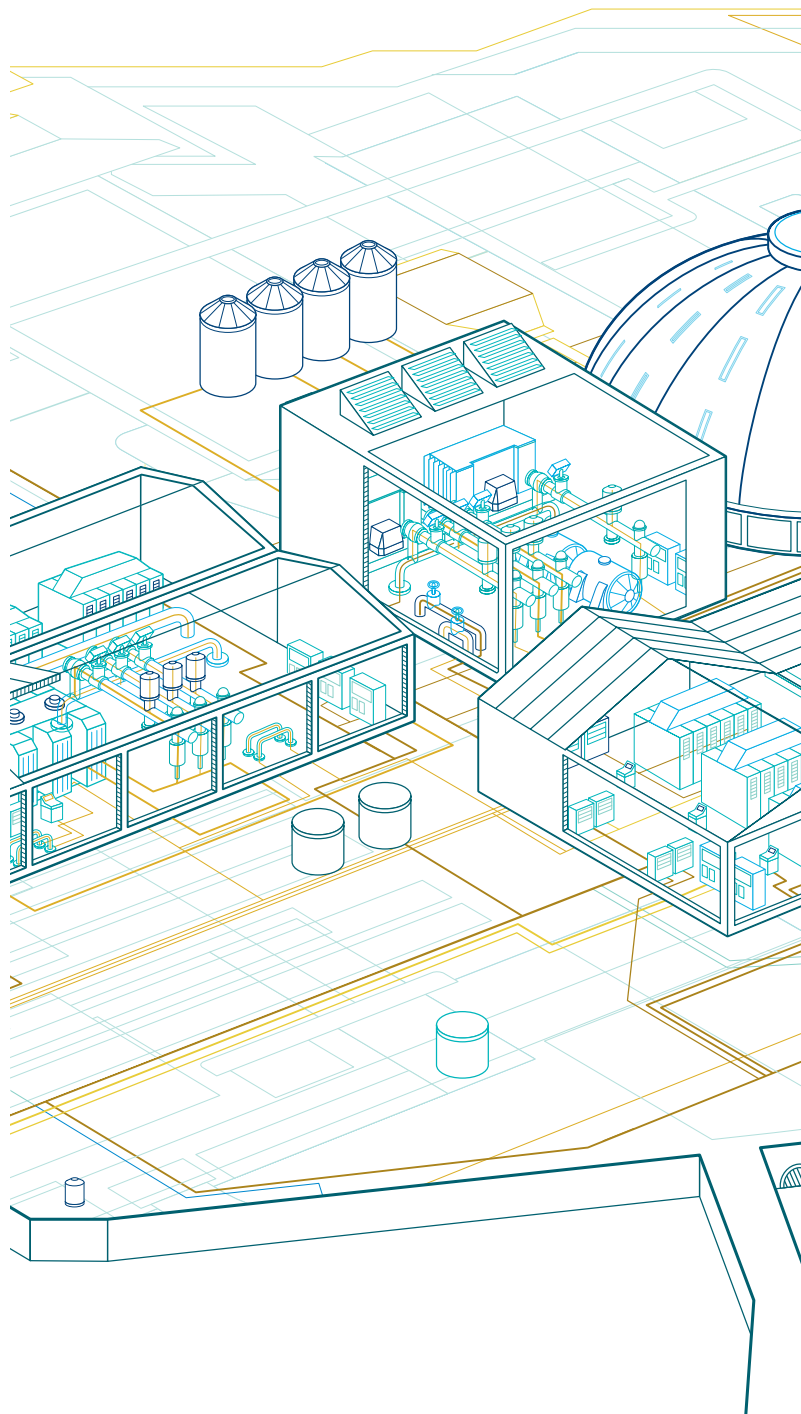
- Boiler feed-water pump
- Condensate extraction pump
- Cooling water pump
- District heating circulation pump

## Fans

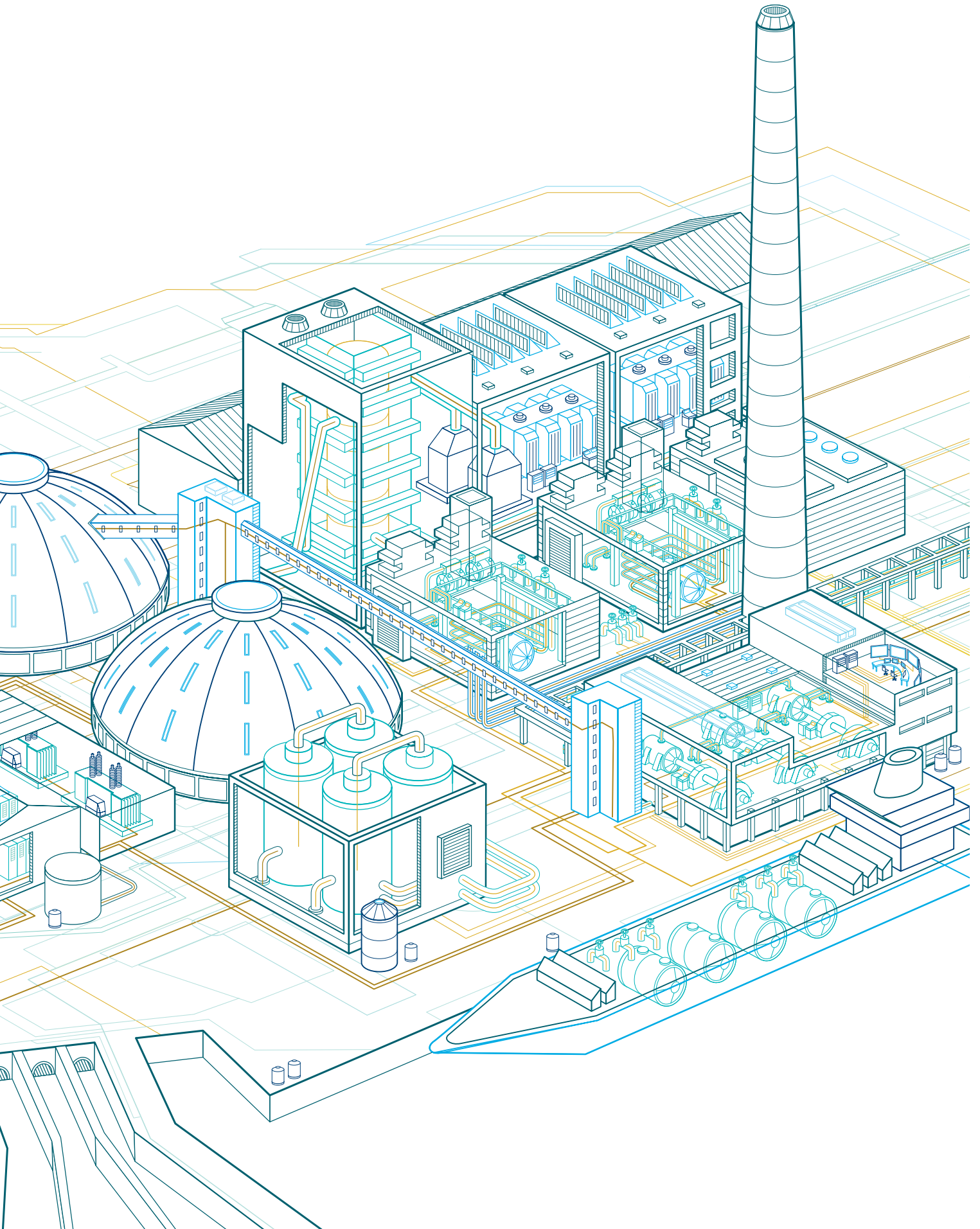
- Primary air fan
- Secondary air fan
- ID fan
- ID booster fan

## Other

- Conveyor
- Coal mill
- Air compressor
- Gas turbine starter
- Fuel gas booster compressor







# Variable speed drives for gas turbine starters and pumped storage power plants

Direct-on-line starting of large synchronous motors causes high starting currents and supply network dips, thermal stress on the motor and mechanical stress on the shaft string.

## Soft starting of pump turbines

Turbines can also be operated as pumps when reversible turbine/generator assemblies are employed. They can pump water back into an elevated reservoir thus storing electrical energy for periods of high energy demand.

In pump operation mode the electric generator acts as motor. Due to the typically large power rating of such a generator/motor direct-on-line starting is practically impossible; even without load.

With ABB's MEGADRIVE-LCI soft starter, starting of large synchronous generators/motors is not a problem. Starting the generator in motoring mode, with the pump turbine unloaded, typically requires less than 10 percent of rated turbine power. The MEGADRIVE-LCI soft starter will continuously ramp-up motor voltage and frequency and smoothly accelerate the turbine from zero to grid synchronous speed. Any impact on the electrical network, such as voltage dips caused by high starting currents, will be minimized. In addition, mechanical and thermal stress on the turbine/generator will be reduced, maintenance costs lowered and the lifetime of the equipment extended.

## Benefits

- Reduced starting impact on network and machinery
- Longer lifetime of equipment
- Starting current limited to rated current or less
- Sequential starting of several machines, even of different power ratings, with a single MEGADRIVE-LCI soft starter
- No speed and no rotor position sensor required

## Gas turbine starters

Gas turbines often have to be started and run up quickly at short notice. MEGADRIVE-LCI gas turbine starters use the generator as motor and run it up to a speed which is above the ignition speed of the gas turbine. From there, the gas turbine can take over and accelerate the generator independently to rated speed and synchronize it to the grid.



## Applications and references

To date, ABB has installed medium voltage drives with a total rated power in excess of 5,000 MW for power generation applications.

### Grosskraftwerke Mannheim (GKM), Germany

ABB supplied medium voltage drives for the refurbishment of the 280 MW boiler of block 6 at GKM's coal-fired power plant in Mannheim, Germany. Two out of three boiler feed-water pumps of 5.8 MW were retrofitted with variable speed drives, replacing the hydraulic couplings which had a poor efficiency.

The replacement resulted in estimated energy savings of 12,000 MWh per year and a reduction of CO<sub>2</sub> emissions by about 10,000 tons per year.

### Mälarenergi, Sweden

ABB supplied medium voltage drive systems to Mälarenergi, a city-owned electric power and district heating provider based in Västerås, Sweden. An energy audit, conducted by ABB, had revealed a huge energy saving potential by upgrading the district heating pumps with variable speed drives. Four resistors and slip-ring motors were replaced with variable speed drive systems, each rated at 1,765 kW.

The heat losses caused by the flow control method were reduced considerably and the production of electrical energy was increased by 35 GWh per year.



GKM power plant, Germany

### Helsinki Energy, Finland

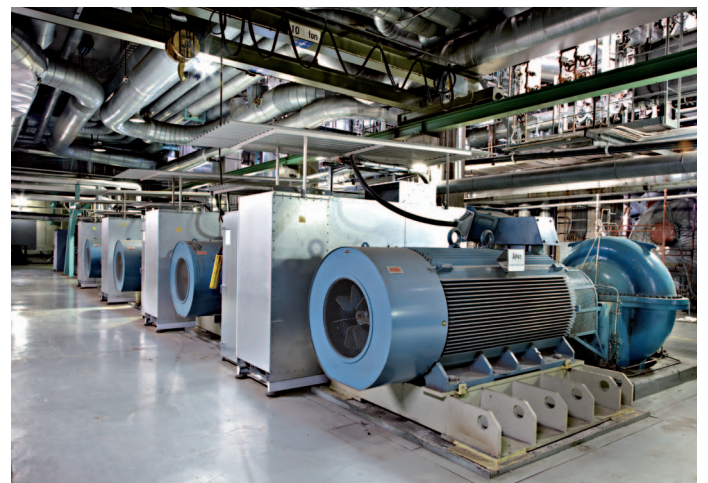
ABB supplied medium voltage drive systems to Helsinki Energy, one of the biggest energy companies producing and distributing electricity and district heat in Finland. The boiler feed-water pumps at Helsinki Energy's combined heat and power (CHP) plant, which were controlled by wound-rotor motors with slip recovery control system, were upgraded with four variable speed drive systems, rated at 4,500 kW.

The upgrade resulted in an improvement of the plant's efficiency and a reduction of maintenance costs.

### University of Illinois, USA

ABB supplied medium voltage drives to the Abbott power plant, owned by the University of Illinois, USA. The plant's scrubber booster fan, which was controlled by inlet vanes, was upgraded with a variable speed drive, rated at 750 kW.

The upgrade resulted in energy savings of \$63,000 per year, a reduction of CO<sub>2</sub> emissions by about 730,000 kg per year and a reduction of maintenance costs by \$10,000 per year.



VSDs, motors and district heating pumps at Mälarenergi, Sweden

## Medium voltage drives

The heart of a medium voltage drive system is the frequency converter. ABB offers the entire range of frequency converters for medium voltage applications in the power range from 250 kW to more than 100 MW.

### **ACS 1000 (315 kW – 5 MW, up to 4.16 kV)**

The ACS 1000 is suitable for both retrofit applications and new standard induction motors. Due to its unique output sine filter, bearing currents and voltage reflections at the motor are eliminated. The ACS 1000i is a fully integrated drive including input transformer and input contactor.

### **ACS 2000 (250 – 1,600 kW, 4.0 – 6.9 kV)**

The ACS 2000 is suitable for retrofit applications and new standard induction motors. It can be used without an input isolation transformer, thereby allowing a direct connection to the line supply (direct-to-line), with an integrated transformer, or for connection to an external input isolation transformer. The ACS 2000 is also available for four-quadrant operation for energy regeneration and reactive power compensation.

### **ACS 5000 (2 – 32 MW, 6.0 – 6.9 kV)**

The ACS 5000 can be applied to standard industrial motors (induction and synchronous). It is ideal for applications in the higher power range such as induced and forced draft fans, feed-water and cooling water pumps. The air-cooled ACS 5000 is also available with integrated transformer.

### **ACS 6000 (3 – 27 MW, up to 3.3 kV)**

ABB's ACS 6000 is a modular drive designed for single or multi-motor applications for both synchronous and induction motors. It can be equipped with an Active Front End which enables four-quadrant operation for energy regeneration and reactive power compensation.

### **MEGADRIVE-LCI (2 – 72 MW or higher on request)**

ABB's MEGADRIVE-LCI is an optimal solution for high voltage and high power applications. Standard designs are available for ratings up to 72 MW; engineered designs for more than 100 MW. The MEGADRIVE-LCI is available as variable speed drive or soft starter.

### **PCS 8000 (25 – 100 MW, up to 6.6 kV)**

The PCS 8000 is the right selection for high power, engineered applications, such as variable speed pump-turbine power plants. It is a modular voltage source converter with optional semiconductor redundancy.



# Technology highlights

Reliability is the main guiding principle of the research and development activities for medium voltage drives.



## Direct Torque Control (DTC)

The ACS drive control platform is based on ABB's award-winning Direct Torque Control (DTC), resulting in the highest torque and speed performance, as well as lowest losses ever achieved in medium voltage drives. Control of the drive is immediate and smooth under all conditions.

## Power loss ride through

Due to its power loss ride through function, the drive system is able to withstand disturbances of the power supply. The drive will continue to operate in an active but non-torque producing mode if the incoming supply voltage is cut off. The drive will be active as long as the motor rotates and generates energy to the drive. It will resume normal operation immediately upon return of power supply.

## Low parts count

The fewer the parts the higher the reliability. ABB uses high power semiconductor switching devices and a topology that minimizes the parts count.

## Fuseless design

ABB medium voltage drives are designed to operate safely without fuses which are known to be unreliable, costly and subject to aging. The fuseless design results in less spare parts and fast re-starting after an overcurrent trip.

## Encoderless

Encoders are known to cause failures. They have an exposed position on the motor. ABB's medium voltage drives can operate without an encoder, thereby reducing maintenance costs and ensuring high levels of availability.

## Remote monitoring and diagnostics

DriveMonitor™ allows secure real-time access to the drive. It supports monitoring and diagnostics of ABB drives independent of the implemented control method, thus also enabling the connection of existent installations.

The optional tool consists of a hardware module, as well as a software layer that automatically collects and analyzes selected drive signals and parameters.

Long-term monitoring functions deliver important information on equipment status, tasks needed and possible performance improvements. Diagnostic procedures and trending can cover not only the converter itself but other parts of the shaft train as well.



# Motors and transformers

ABB drive packages include medium voltage converters, motors and transformers.

ABB can offer the complete variable speed drive system or assist in selecting components that match the process requirements. ABB's equipment is known for its state-of-the-art technology, high efficiency and reliability and world-wide support.

## Converter motors

ABB's converter motors have earned an excellent reputation for performance and reliability. ABB's product range includes induction as well as synchronous motors.

Induction motors are the workhorses of the industry due to their versatility, reliability and simplicity. In the power range up to 10 MW, a squirrel cage induction motor is usually the first choice. They are available up to 22 MW.

Synchronous motors are typically considered for higher power ratings (eg above 8 MW to more than 100 MW). In addition to their high power capabilities, synchronous motors offer the benefits of high efficiency and high performance through the utilization of different rotor designs.

## Converter transformers

Converter transformers are especially designed for operation with variable speed drives. They adapt the converter to the supply network and provide a galvanic isolation between drive and supply network.

Converter transformers are available for nearly all ratings. Secondary voltages are optimized to match the converter and motor voltage. Oil or dry types for indoor or outdoor mounting are available. Busbar connections can also be provided.



# Testing, service and support

ABB drives are backed by comprehensive service and support, from the customer's initial inquiry throughout the entire life cycle of the drive system.

## Testing

ABB is committed to ensuring the reliability of every drive it delivers. To verify that quality standards and customer requirements are fully met every component of a drive is subjected to thorough testing in ABB's modern test facilities.

Routine tests and functional tests form an integral part of the scope of supply of ABB's medium voltage drives. They are performed in accordance with international standards and ABB quality assurance procedures.

Additionally, ABB can perform a combined test with the complete drive system – including transformer, converter and motor – to verify the performance and to ensure a smooth integration into the customer's facility.

## Installation and commissioning

Proper installation and commissioning of the equipment, done by qualified and certified commissioning engineers, reduces start-up time, increases safety and reliability and decreases life-cycle costs. In addition, operators can be given practical training by experienced specialists on site.

## Life-cycle management

ABB's drive life-cycle management model maximizes the value of the equipment and maintenance investment by maintaining high availability, eliminating unplanned repair costs and extending the lifetime of the drive.

Life-cycle management includes:

- providing spare parts and expertise throughout the life cycle
- providing efficient product support and maintenance for improved reliability
- adding functionality to the initial product
- providing a smooth transition to a new technology at the end of the life cycle

## Training

From basic tutorials to tailored training, ABB provides extensive training for its medium voltage drives. A range of training programs is offered from basic tutorials to programs tailored to the customer's specific needs.

## Global network, local presence

After sales service is an integral part of providing the customer with a reliable and efficient drive system. The ABB Group of companies operates in more than 100 countries and has a worldwide network of service operations.



## Services for ABB's medium voltage drives

- Supervision of installation and commissioning
- Training
- Remote services
- Preventive maintenance
- Customized service agreements
- Local support
- 24 x 365 technical support
- Spare parts and logistics network
- Worldwide service network

# Contact us

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