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ABB DRIVES

## **Efficient refrigeration control**

Reducing operating costs and  
CO<sub>2</sub> emissions using AC drives



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**Refrigeration can account for up to 70 percent of the electricity bill for companies in the food manufacturing sector.**

**Energy-efficient drive and motor solutions help to reduce energy consumption while making food safety a priority.**

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## The potential for energy savings in refrigeration systems

30 percent of the world's electrical energy use goes to powering electric motors, the majority of which are for industrial use. The food and beverage industry is one of the largest consumers of energy and one of the biggest users in this sector is refrigeration.

Refrigeration systems can consume up to 70 percent of the total electrical energy used in a food & beverage plant. Yet, even today, these systems have one of the most overlooked opportunities for energy saving. Realizing these potential savings can cut costs significantly, boost profitability and reduce CO<sub>2</sub> emissions. Variable-speed drives (VSDs; also referred to as variable frequency drives – VFDs) are an efficient tool to optimize the energy consumption of conditioned atmosphere and refrigeration processes.

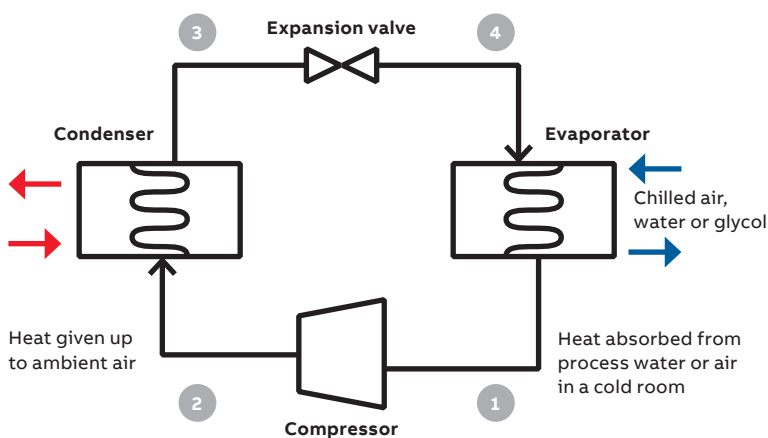
Since cold storages and refrigeration plants typically run 24/7, most refrigeration applications are potential VSD candidates. Any refrigeration system with a wide load variation during its operating hours, or with a heat load that is less than the peak load, can benefit from a VSD.

The motors driving refrigeration systems are normally run at a constant speed even though the load is varying. Using VSDs the speed of the motor can be varied to meet the dynamic load demand, thereby reducing the amount of energy consumed.

Variable-speed control can also increase the lifetime of the equipment. Instead of running at full speed continually, the lower speed reduces stresses on the equipment, extends service intervals and cuts maintenance costs.

VSDs can be retrofitted to many existing systems. The speed of the electric motor is then directly controlled by the VSD, with the mechanical controls generally left fully open.

Overview of typical industrial refrigeration cycle.



### Step 1:

At this point the refrigerant has just left the evaporator and is a cold gas.

### Step 2:

The cold gas enters the compressor and is compressed and discharged as a hot gas. The gas passes to the condenser where it gives up its latent heat of evaporation to either air or water. At the same time it returns to its liquid state.

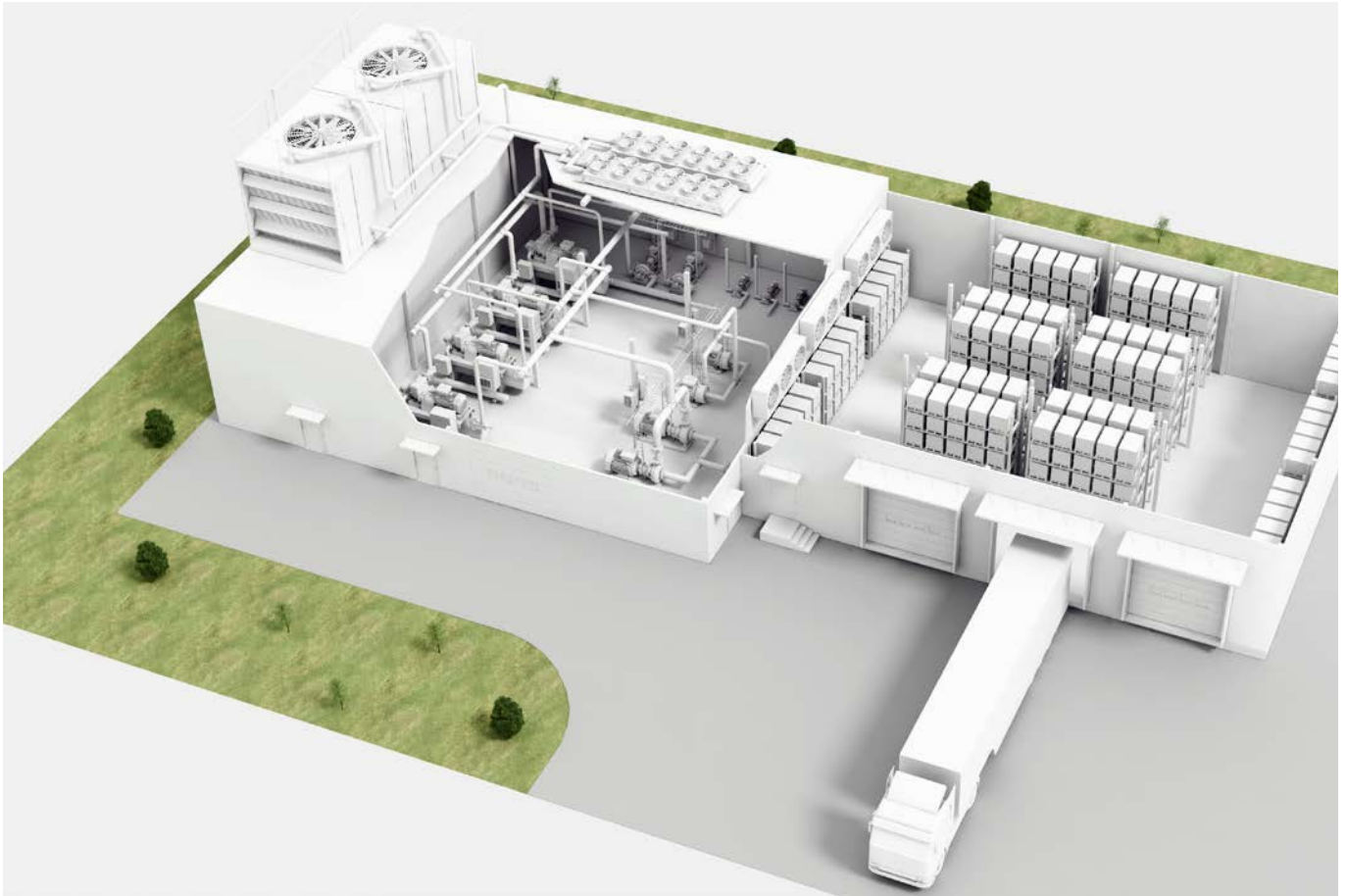
### Step 3:

The hot liquid refrigerant next passes through the expansion valve, where it is expanded and cools to become a cold liquid.

### Step 4:

The cold liquid refrigerant enters the evaporator. It absorbs heat from the product in the refrigerator or cold store, which causes it to evaporate into a cold gas.

## Industrial refrigeration systems



Compressors, condensers and evaporators are widely used throughout industrial refrigeration systems.

Screw and reciprocating compressors, air or water-cooled condensers and DX or flooded evaporators are widely used throughout industrial refrigeration applications from cold rooms through to blast freezing, where refrigerant temperatures can reach  $-45^{\circ}\text{C}$ . The systems are generally larger than those in the retail sector, often in excess of 500 kW and utilising several compressors to obtain high capacity.

In traditional systems, compressor capacity is varied by stopping and starting compressors together with slide valve control for screw compressors and by switching capacity control valves on reciprocating compressors. When refrigeration demand is low, compressors are

switched off in a controlled sequence and restarted when demand increases.

Condenser fans use on-off control, sometimes enhanced by two-speed operation if a broader control range is required. Evaporator fans are stop-started as required.

While these systems have operated well for decades, a greater awareness of operational costs, particularly energy consumption, and the need to use more environmentally friendly refrigeration systems, had led to the use of VSDs and high efficiency motors becoming more widespread.

# Compressors

## Challenge

**Screw compressors** in traditional systems run at fixed speed, with capacity control via slide valve operation. Slide valves work either by reducing the swept suction volume (by bypassing the suction gas) or by reducing the compressed volume ratio, or both. However, power consumption does not reduce in proportion with capacity, and screw compressors operating at fixed speed and low capacity are therefore inefficient.

Common methods of adjusting the cooling capacity of **reciprocating compressors** are blocked suction system, cylinder unloading, hot gas bypass and suction pressure control. In these methods of capacity control the energy consumption is not proportional to the cooling capacity demand. For example, for a cooling capacity demand of 50 percent, the compressor will typically absorb around 65 percent of full capacity power.

Capacity control of **scroll compressors** are typically achieved using on/off or lifting scrolls. The on/off control uses higher energy than what is proportional to the cooling demand due to pressure cycling and transient losses.

## Solution

When variable-speed control is applied to a screw compressor, the slide valve becomes largely redundant. It only needs to be used if it is necessary to control capacity below the minimum speed (typically 25 Hz). At all higher speeds capacity can be adjusted by using the drive to vary the operating speed while the slide valve is kept open. When the slide valve is open recirculation does not occur, which allows significant energy savings.

As the graph shows, when a slide valve is used to decrease the refrigeration capacity of a screw compressor to 40 percent, its power consumption only reduces to around

60 percent. With a VSD, by contrast, the reductions in refrigeration capacity and power consumption are essentially equal.

Some modern screw compressor designs have eliminated the slide valve altogether and are sold specifically for variable-speed operation.

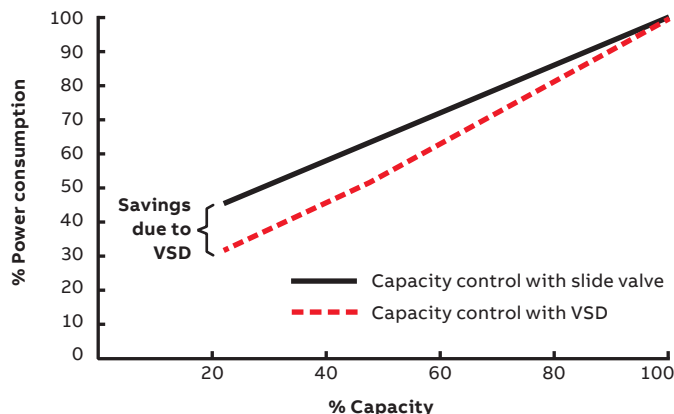
## Benefits

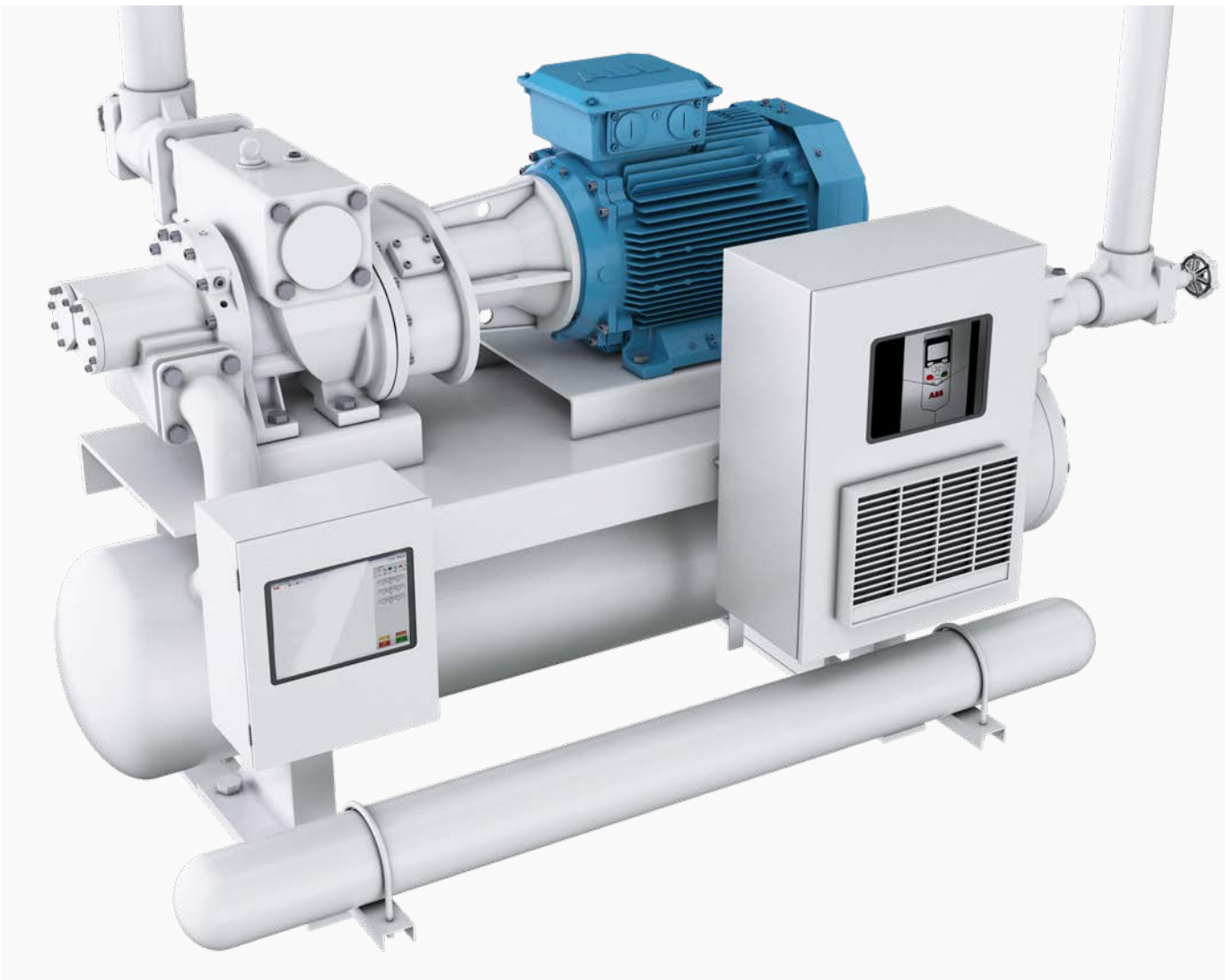
Variable-speed control enables **screw compressor** capacity to be increased by over-speeding up to 60 Hz, whereby on a new installation the compressor frame size could be smaller for an equivalent capacity. Some increase in capacity may also be available when carrying out retrofits as long as the system can cope with higher outputs. A combination of variable-speed control and floating head pressure control will fully optimize the system. Floating head pressure control varies the head pressure (ie, the pressure of the gas exiting the compressor) in line with ambient temperature conditions, rather than maintaining the head pressure at a fixed, higher level. Energy savings of 15 to 25 percent are typically achievable, with even greater savings possible in certain cases.

The control of **reciprocating compressors** with VSDs allows the compressor speed to be continuously adapted without stop/go, thus reducing the energy consumed and increasing the lifetime of the compressor. Variable-speed control ensures less refrigeration and heat losses in the system, and an optimized use of energy based on the actual refrigeration requirement.

Variable-speed controlled **scroll compressors** can be adapted to varying cooling loads using 30 percent less energy compared to on/off control method. In addition, variable-speed drives reduce the starting current and allow a stable and precise temperature control.

Capacity control on a screw compressor: slide valve versus VSD.





**Advantages of compressor speed control by VSD:**

- Stable suction pressure ensures stable cold room temperature
- Increased capacity using a smaller compressor
- Multi-compressor control
- Oil return management with minimum speed supervision
- Speed control to achieve set evaporator temperature
- Reduced wear and tear
- Reduced start current
- Extended compressor lifetime
- Lower maintenance costs
- Increased capacity due to capability of running above nominal speed
- No limitation on number of starts per hour
- Fast ramp up of scroll compressors to minimum speed

In applications where speed reduction is not the primary objective, eg when the compressor provides base line cooling as part of a bigger system, we recommend using softstarters.

**Advantages of softstarters compared to direct start:**

- Reduced start current
- Reduced wear and tear
- Extended compressor lifetime
- Lower maintenance costs
- Bus communication







## Pumps

### Challenge

Systems using chilled water or glycol as the cooling medium require a pump to circulate the coolant around the plant. The water/glycol supply temperatures typically range from -8 °C to greater than +10 °C with the return temperature some 5 °C higher. This temperature increase, referred to as delta T, results from the heat drawn from a production area or cold store. Delta T is the key parameter for the control system and once it is determined, all the equipment – including compressors, heat exchangers and pumps – is designed to achieve delta T. The pumps are therefore selected to deliver the required flow rate of chilled water/glycol through the plant in order to achieve delta T across each load.

### Solution

In traditional systems, this flow rate is often preset by using a flow control (throttling) valve, which is adjusted at the commissioning stage to obtain the desired results. However, preset flow rates do not take varying load characteristics into account, and they often result in wasted energy because the actual flow rate is higher than required to remove the heat load. Optimal control is obtained by varying the flow of chilled water/glycol through the plant to match the heat load. Upgrading the coolant pumps to variable-speed

operation allows the control valve to be kept fully open, and the flow is varied according to the heat load demand. Fully opening the control valve also eliminates the resistance introduced by throttling, providing an additional energy saving. A further benefit of VSDs is that it is possible to set a minimum flow rate (minimum speed) as required by the chiller evaporative circuits to avoid freezing of the coils.

Reducing the speed of the pump delivers electrical power savings based on the cube of the reduction. The table below shows examples of the approximate savings that can be achieved:

Reduction in pump speed (%)	Reduction in absorbed power (%)
5	15
10	30
20	50

### Benefits

It can be seen that even small reductions in speed can result in substantial savings in power and electricity costs. The use of a VSD in closed loop PID (proportional-integral-derivative) control to regulate temperature or pressure optimizes energy savings by matching pump delivery to the flow requirement.

## Evaporators

### Challenge

Cold liquid coolant flowing from the expansion valve into the evaporator is boiled off by heat from the product under refrigeration, becoming a cold gas that continues on to the compressor. In conventional refrigeration systems, where the compressor is always operated at full speed, the cooling output is regulated by the evaporator. At the same time the expansion valve seeks to achieve an optimal fill of the evaporator. Interaction between the operation of the evaporator and that of the expansion valve gives rise to oscillation in the system. As a consequence, the evaporator is not completely filled and therefore operates inefficiently.

### Solution

The performance of fans is governed by the cube law. In other words, the amount of power required by an evaporator fan motor is proportional to the cube of its

speed. Variable-speed control can therefore achieve major energy savings by modulating the fan speed according to the cooling demand. When fan speed is reduced by 20 percent, for example, the power requirement will fall by about half. The potential for energy savings naturally depends on the specific installation and cooling load, but in many cases it is possible to cut the electricity consumption of evaporator fans by as much as 80 percent.

### Benefits

Speed control provides outstanding space temperature control relative to cycling. Fan noise is reduced at lower speeds, creating a more pleasant work environment in facilities like distribution centers. In some cases reduced fan speed improves storage of perishables, such as apples in a controlled atmosphere, as mass loss from fruit is reduced when using speed control.

# Condensers



Using variable-speed drives to control condenser fans can increase efficiency by up to 15 percent.

## Challenge

The condenser receives high pressure superheated vapor from the compressor. The vapor cools down in the condenser and returns to its liquid form. This is the point at which all of the system heat is dissipated to the ambient.

Simple control systems use conventional contactors to switch the condenser fans on or off. These systems are sometimes enhanced with two-speed operation in an effort to improve system control. The most common control method is to regulate condenser fan speed in order to maintain a fixed system discharge pressure.

Condenser fans are often controlled by pressure switches or step controllers, which switch the fans on and off to maintain a specific set point. This method forces the compressor to maintain a specific head pressure at all times and this generally corresponds to the point where the system was designed to operate during the hottest days of the year.

## Solution

Increasingly, the favored approach is to use more intelligent control systems. These involve the use of VSDs to drive the condenser fans and allow the head pressure to be reduced.

The fans may work a little harder and consume more energy but the corresponding reduction in discharge pressure saves a proportionately greater amount of energy by reducing the compressor load.

## Benefits

Variable-speed condenser fan control uses a drive or drives to control the speed of all the fans simultaneously. This provides floating point head pressure control and efficient fan operation, while utilizing the entire condenser surface area.

The control system sets the speed of the fans to ensure correct condensing conditions, optimizing fan power consumption and overall system efficiency.

When the correct operating conditions are established, on-off cycling of the fans is minimized, while lower air velocities reduce condenser fouling.

Refrigeration efficiency can generally be improved by up to 15 percent with variable-speed condenser fan control.

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## Further benefits of variable-speed control

### Decreased maintenance

Variable-speed control delivers smooth acceleration and deceleration of motors, which helps to reduce stress on belts and/or couplings, and extend their lifetimes. This can be contrasted with direct-on-line starting, where the motor and load accelerate at the highest rate. This stresses the belt, reducing its lifetime and requiring more frequent replacement and maintenance than with VSD control. The same applies to conventionally controlled two-speed fans: electrical braking stresses the motors as the fans slow down. VSDs also require less electrical maintenance than conventional control gear.

### Lower noise levels

VSDs help to reduce noise levels when they are used to control condenser fans. Fan noise diminishes substantially with rotation speed, so when refrigeration demand is low – at night, for example – the risk of noise disturbance to people living nearby is minimized.

### Reduced starting current

Larger motors, like those used on refrigeration compressors, draw high currents when starting. Common mitigation methods applied in conventional systems include star-delta starting and electronic softstarters. Star-delta starting reduces starting torque but still generates high current

peaks and transient surges, and it requires more regular maintenance. Electronic soft starting reduces the overall current level, however the starting current for large motors can still be surprisingly high. Typically, for a 315 kW motor, soft start currents might reach 2,000 A or more. With variable-speed control, starting currents never exceed the full load current of the motor – a major advantage over conventional starting methods.

### Longer motor lifetimes

When motors are operated at reduced speed (and load) the lifetime of the bearings is increased. At the same time the motor's core temperature can be reduced, which increases the insulation life and further enhances bearing lifetime as less heat is conducted along the shaft to the bearings.

### New installations and retrofits

ABB drives are the ideal choice for both new installations and retrofits into existing systems. Based on our broad experience of refrigeration systems, we help you to select the right products for your plant. In addition to VSDs, we supply the necessary inverter rated motors for new installations as well as appropriate filtering for motors where drives are retrofitted into an existing system.

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Correct maintenance is vital for best performance of equipment.

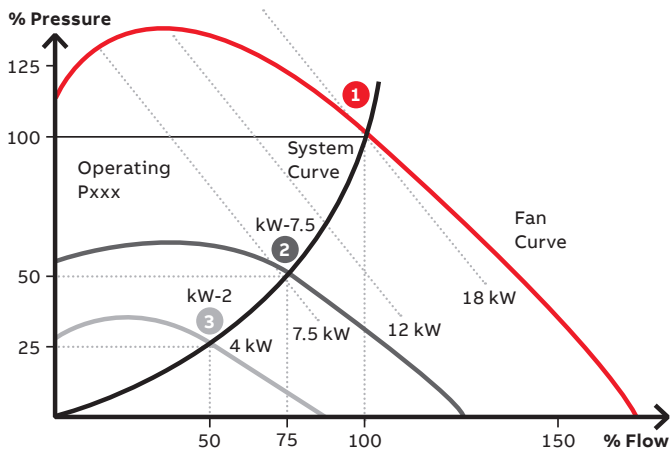






## Saving energy with variable-speed drives

Investments in new industrial refrigeration equipment are often constrained by tight controls on capital expenditure (CAPEX). Unfortunately, this can lead to much higher lifetime operational expenditure (OPEX), such as energy and maintenance costs. In fact, energy is one of the largest costs over the life cycle of an industrial refrigeration system. When investing in a new system it is therefore vital to determine the right balance between CAPEX and OPEX. Spending a little more on the initial investment can significantly reduce lifetime costs, so the payback time for the additional investment is very short.



### Compressors

Refrigeration systems typically run 24/7 and for many food and beverage companies refrigeration is the biggest energy user. Cooling compressors can account for over 50 percent of a typical factory's electricity bill. By operating compressor motors according to load requirements – ramping the motor speed up and down in line with demand – VSDs enable big savings.

A public cold storage warehouse in the US added 26 ABB VFDs to the motors powering the compressors, evaporators and condensers, the primary components of the entire refrigeration infrastructure. Most striking was the savings in energy costs, as the facility immediately realized an electrical energy consumption savings of 35 percent, providing a six-month return on the up-front investment of the drives.

### Pumps and fans

For compressors, the relationship between a motor's speed and the amount of power it uses is linear. In the case of pumps and fans, power varies with the cube of the speed. This means that reducing the speed by half will reduce the power by a factor of 8.

The figure shows the practical effects of this cube law as it applies to variable-speed fan control. At Point 1 the fan is operated at 100 percent airflow and requires 18 kW. When the airflow is reduced to 75 percent (Point 2), the drive will run the motor at 75 percent speed, which will require only 7.5 kW. Reducing the airflow by 25 percent has resulted in a decrease of over 58 percent in required power.

Putting these potential savings into context, for a cold storage evaporator (supply) fan rated 18 kW and running 24/7, annual power consumption will be:

- 171,975 kWh running at constant speed
- 53,430 kWh controlled by a variable-speed drive

Using a VSD reduces power consumption by more than 68 percent (calculated on the basis of the cube law and assuming the fan curve's duty cycle follows a standard bell shape at reduced flow).

Taking a real-life example, a British duck meat processing company wanted to reduce the electricity consumption of its refrigeration plant. The condenser fans were connected direct-on-line, and an on-site energy analysis showed that they required 38 kW of power. ABB variable-speed drives were installed to operate the fans. The head pressure signal was used to control the VSDs so the drives kept the pressure at its design point, varying the speed of the fans to meet the chilling demand. A second energy analysis after installation of the drives showed that the fans' power requirement was reduced by 13 kW, or more than one third. Furthermore, reduced on-off cycling of the refrigeration plant led to a further 10 percent reduction in compressor power. Fan noise decreased significantly, improving environmental conditions for neighboring properties.

Following the upgrade to the condenser fans, the plant has installed ABB drives on its air compressors, water pumps and other equipment, and reports that the energy consumption of these applications has dropped by nearly 50 percent overall. The payback time for the investment in drives was less than eight months.

# ABB motion solutions – highly efficient, reliable and cost-effective

ABB offers a wide range of products for refrigeration and cooling applications.

## Variable-speed AC drives

### Unrivalled energy efficiency

- Lower reactive power consumption
- High efficiency of 98 percent
- Energy, CO<sub>2</sub> and money saved calculators built-in
- Energy optimization function built-in
- Flux optimization for reduced energy consumption

### Precise control and high dynamics

- Direct torque control (DTC) for extremely accurate control
- Pump-Fan-Compressor Control as standard
- Load profile monitoring
- Multi-Pump-Fan-Compressor Control as standard
- Excellent performance in abnormal situations including:
  - short supply voltage breakdown
  - heavy variations of torque
  - motor already rotating
  - cable short-circuits

### Enhanced safety, reliability and convenience

- SIL 3 safety
- Safe Stop
- Lower noise levels
- Sleep mode
- Dry running protection for pumps
- IP55 enclosure class with main switch option
- Flange mounting option

### Wide range of interactive assistants

- Startup
- Up to 4 PID loop controls
- Timer functions
  - Built-in real-time clock
- Serial communication
- Diagnostic
- Maintenance

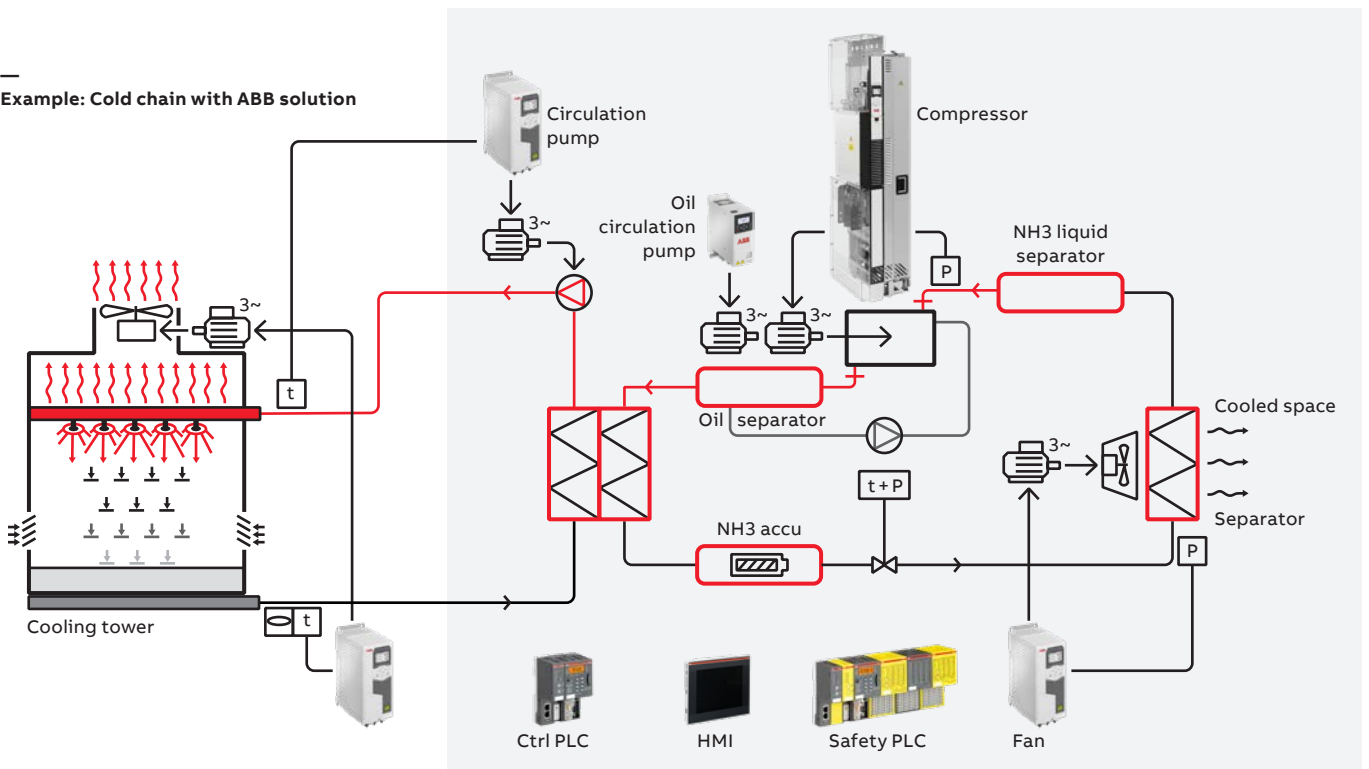
## Softstarters

- Cover any motor application from 3 A to 2160 A
- Reduced starting current and less electrical stress on the motor and the network
- Fast and easy to install and set-up with a small footprint
- Reduced mechanical wear and tear on mechanical equipment

## PLCs and HMIs

Our PLCs and operator panels along with Automation Builder software allow you to develop any range of control needed.

## Example: Cold chain with ABB solution





# Tackling the problem of harmonics

## What are harmonics?

Harmonic currents are created by non-linear loads connected to the power distribution system. Harmonic distortion is a form of pollution in the electric plant that can cause problems if the voltage distribution caused by harmonic currents increases above certain limits.

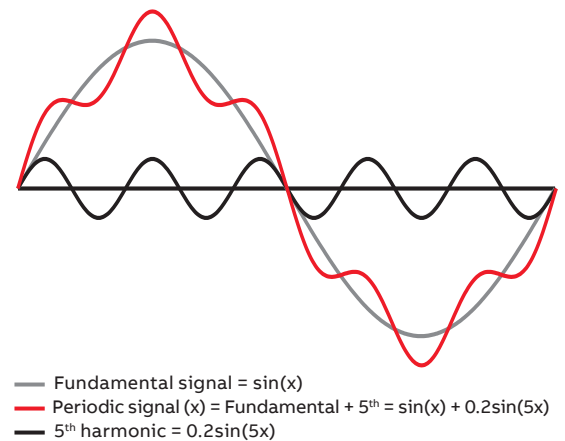
All power electronic converters used in different types of electronic systems can increase harmonic disturbances by injecting harmonic currents directly into the grid.

Electricity supply is hardly ever a pure sine wave voltage, and current that deviates from the sine form contains harmonics. The distortion is caused by non-linear loads connected to the electrical supply. Harmonics cause disturbances and equipment failures.

By choosing ABB ultra-low harmonic (ULH) drives, you can automatically make your plant more reliable. Compared to a conventional drive, the harmonic content is reduced by up to 97 percent. The total harmonic current distortion of an ABB ULH drive is typically <3 percent in a nominal situation and an undistorted network.

Built-in chokes in standard 6-pulse drives mitigate harmonics reducing disturbances and equipment failures. Smaller harmonic content also saves money and makes the installation easier because it allows smaller fuses and longer motor cables to be used. Finally, less harmonics means also longer lifetime for the components and thus less maintenance needs and downtime.

The total current as the sum of the fundamental and 5<sup>th</sup> harmonics



**Clean network**



**Reliable operation**



**Reduced cost**



**Longer lifetime**

## Highlights of ABB ultra-low harmonic drives

- The total harmonic current distortion is typically <3 percent in nominal situation and undistorted network. Low harmonic content also at partial loads.
- “All inside” design: no need for external filters, multi-pulse arrangements or special transformers
- Simple and cost-effective installation
- Unity power factor. Possibility for network power factor correction
- Small installation footprint
- Output voltage stabilization secures operation in weak networks
- Stable output voltage in all load conditions

## Life cycle services

### Service options for variable-speed drives

Although drives are not normally the most expensive pieces of capital equipment, they often perform critical duties and have a high in-service value.

A drive failure can result in loss of production and revenues, as well as having safety and environmental consequences. To reduce the risk and consequences of failure, the drive must be properly maintained at the right times in its life cycle.

### Life cycle services

The services offered by ABB span the entire value chain, from the moment a customer makes the first enquiry to disposal and recycling of the drive. Throughout the value chain, ABB provides training, technical support and customised contracts. All of this is supported by one of the most extensive global drive sales and service networks.

### Prepurchase

ABB provides a range of services that help guide the customers to the right products for their applications. These include:

- Energy appraisals (see next page)
- ATEX (see next page)
- Harmonics
- EMC

### Order and delivery

Orders can be placed directly to ABB or through ABB's channel partners. ABB's sales and service network offers timely deliveries including express delivery.

### Installation and commissioning

While many customers have the resource to undertake installation and commissioning on their own, ABB and its channel partners offer professional installation and start-up services.

### Operation and maintenance

From site surveys to preventive maintenance and reconditioning of drives, ABB has all the options covered to keep its customers' processes operational.

### Upgrade and retrofit

An existing ABB drive can often be upgraded to the latest software or hardware to improve the performance of the application. Existing processes can be economically modernised by retrofitting the latest drive technology.

Prepurchase

Order and  
delivery

Installation and  
commissioning

**Replacement and recycling**

ABB can advise on the best replacement drive while ensuring that the existing drive is disposed of in a way that meets all local environmental regulations.

**Entire value chain services**

The main services available throughout the entire value chain include:

- Training and learning – ABB offers product and application training both in classrooms and on the internet
- Technical support – At each stage of the value chain, an ABB expert is available to offer advice to keep the customer's process or plant operational
- Contracts – Customised contracts can be devised between the customer and ABB

**Energy appraisal**

Simply walking around a plant, factory or shop floor can reveal the potential VSD opportunities on refrigeration systems. A look at the position of slide valves on screw compressors can indicate whether VSDs are a suitable option.

A similar inspection of the position of throttle valves on pumps can be revealing. If the valves are mostly partially closed, this is a good retrofit candidate.

Alternatively potential retrofit candidates can be identified by taking flow and power measurements and comparing these figures to the rated flow and power of the system under study. ABB can help to identify suitable applications that can benefit from a VSD.

**ATEX**

Industrial refrigeration systems in potentially explosive atmospheres need to conform to ATEX 94/9/EC Directive [ATmosphères EXplosives]. Industrial refrigeration components are mainly used in ammonia refrigeration systems, but some components are used in related applications, where locations are classified as hazardous areas.

Operation and  
maintenance

Retrofit and  
upgrade

Replacement and  
recycling









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For more information, please contact  
your local ABB representative or visit

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