CARBON TRUST

# Variable speed drives

Introducing energy saving opportunities for business

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# Preface

Reducing energy use makes perfect business sense; it saves money, enhances corporate reputation and helps everyone in the fight against climate change.

The Carbon Trust provides simple, effective advice to help businesses take action to reduce carbon emissions, and the easiest way to do this is to use energy more efficiently.

This technology guide discusses variable speed drives (VSDs) and lists energy saving opportunities for businesses. It demonstrates how installing VSDs in appropriate applications could save energy, cut costs and increase profit margins.

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# Technology overview

Electric AC induction motors run at fixed speeds and are ideally suited to applications where a constant motor output speed is required.

However around half of all motor applications have some kind of varying demand and this includes processes such as moving air and liquids (fans and pumps), winding reels and precision tools.

Historically in applications requiring precise speed control such as paper winding reels expensive direct current (DC) motors or hydraulic couplings were used to regulate the machine speed, whereas in other applications the processes have been controlled by opening and closing dampers and valves, or changing output speeds with gears, pulleys, and similar devices whilst the motor speed remained constant.

In the 1980's and 1990's variable speed drives (VSDs) started appearing on the market offering an alternative method of control. A VSD, also known as a 'drive', 'frequency converter', 'adjustable speed drive' or 'inverter', is an electronic power controller that is able to adjust the electrical supply to an AC induction motor with a corresponding change in the motor's speed and torque output.

By implementing this type of control a very close match between motor speed and the process requirements of the machine it is driving may be achieved.

VSD technology is now mature and enjoying widespread adoption and use with AC induction motors; VSD's are extremely versatile and offer a high degree of motor control where motor speeds can be accurately varied from zero rpm through over 100% of the rated speed, whilst the torque is also adjusted to suit.

Different options are available to suit a variety of applications; basic VSD designs are used in simple applications such as fan and pump control whereas more complex versions might be used for very precise speed and torque control in for example multiple winders or materials forming applications.

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Sizes of VSD range from 0.18kW through to several MW; they are usually available as standalone devices and are connected to the motor’s electrical supply, however on some smaller motor designs, usually under 15kW the VSD may be built onto the motor and is available as an integrated motor-drive product.

In many applications variable speed control can lead to a substantial reduction in energy use. The use of VSDs is particularly effective in fan and pump applications where they might be used to replace traditional methods of output regulation; here an exponential relationship exists between the machine speed (and output) and the energy used.

## Did you know?

Using a VSD to slow down a fan or pump motor from 100% to 80% can save as much as 50% on energy use.

*Figure 1* ***S100 ip66***

# Principle of operation

Whilst there are a number of variations in VSD design; they all offer the same basic functionality which is to convert the incoming electrical supply of fixed frequency and voltage into a variable frequency and variable voltage that is output to the motor with a corresponding change in the motor speed and torque. The motor speed can be varied from zero rpm through to typically 100-120% of its full rated speed whilst up to 150% rated torque can be achieved at reduced speed. The motor may be controlled in either direction.

VSDs applied to AC induction motors are by far the most common. Their basic design consists of four elements:

**1. Rectifier:** the rectifier changes the incoming alternating current (AC) supply to direct current (DC). Different designs are available and these are selected according to the performance required of the VSD. The rectifier design will influence the extent to which electrical harmonics are induced on the incoming supply. It can also control the direction of power flow.

**2. Intermediate circuit:** the rectified DC supply is then conditioned in the intermediate circuit, normally by a combination of inductors and capacitors. The majority of drives currently in the marketplace use a fixed-voltage DC link.

**3. Inverter**[1]**:** the inverter converts the rectified and conditioned DC back into an AC supply of variable frequency and voltage. This is normally achieved by generating a high frequency pulse width modulated signal of variable frequency and effective voltage. Semiconductor switches are used to create the output; different types are available, the most common being the Insulated Gate Bipolar Transistor (IGBT).

**4. Control unit:** the control unit controls the whole operation of the VSD; it monitors and controls the rectifier, the intermediate circuit and the inverter to deliver the correct output in response to an external control signal.

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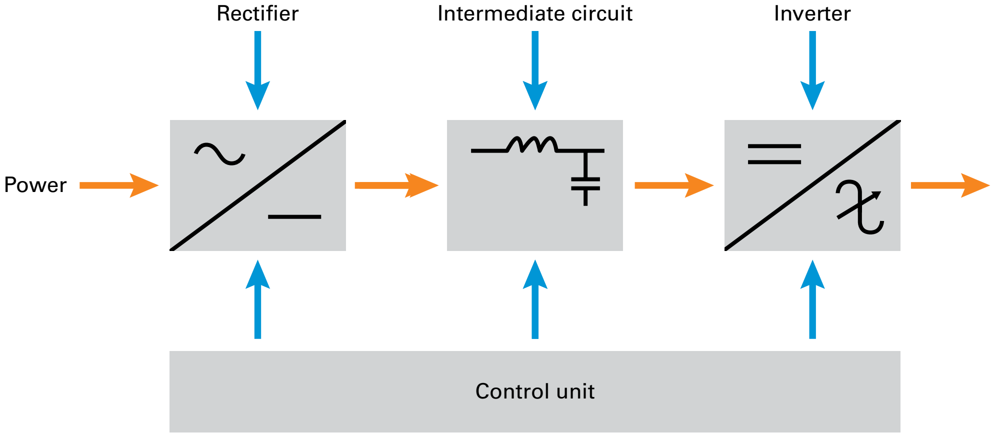
[1] VSD units are also commonly referred to as ‘inverters’. See the glossary at the end for further information.

*Figure 2 Schematic of a VSD*



VSDs are typically 92-98% efficient with 2-8% losses being due to additional heat dissipation caused by the high-frequency electrical switching and the additional power required by the electronic components.

Equally motors connected to VSDs experience some additional losses due to heating caused by the high frequency electrical switching.

## Installation of VSDs

Electrically, a VSD is installed in series between the mains electrical supply and the motor.

Large VSDs can introduce electrical 'pollution' in the form of harmonics onto the supply which can be detrimental to other equipment; in the UK regulations such as EA Engineering Recommendation G5/4 limit the amount of harmonics that are permitted on the supply; depending on the local circumstances the installer will have to consider installing electrical filters or specify the rectifier type to ensure compliance is achieved.

Most VSDs offer computing intelligence and are able to be connected to a variety of control systems and sensors. A basic VSD will be able to control a motors output in response to a control signal in order to achieve the desired operating condition. In the simplest of applications the VSD will be interfaced to a transducer such as a pressure, or flow rate sensor, and then programmed to maintain a preset value (set point).

At the other end of the spectrum advanced VSDs can perform complex process control tasks; they may be interfaced to a number of transducers, implement interlocks and other control functions, and interface with modern computer networks providing real time operating data.

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Being electronic equipment VSDs are susceptible to damage through dust and humidity ingress, or inadequate cooling. They should be located near the motor in suitably ventilated enclosures or remotely in a suitably protected area. Larger drives can generate a lot of heat, and this must be removed or the unit will eventually overheat and fail.

## VSDs

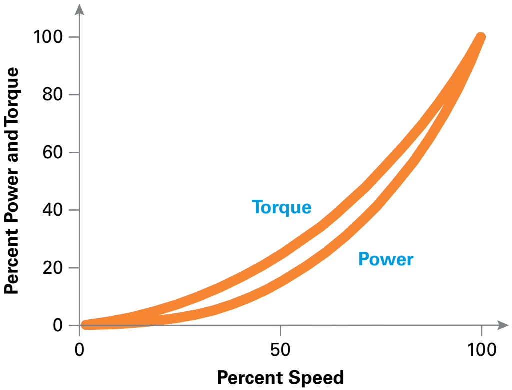
VSDs have the potential to make energy savings and increase profitability in almost every sector of UK business.

Large VSD mounted in ventilated enclosure (Courtesy of Siemens)

# Load types – typical savings & other benefits

The potential for energy saving from slowing down the load depend on the characteristics of the load being driven. There are three main types of load: variable torque, constant torque and constant power.

*Figure 3 Variable Torque Load Profile*



## 1. Variable torque load

Variable torque loads are typical of centrifugal fans and pumps and have the largest energy saving potential.

They are governed by the Affinity Laws which describe the relationship between the speed and other variables:

The change in flow varies in proportion to the change in speed:

$Q1/Q2 = (N1/N2)$

The change in head (pressure) varies in proportion to the change in speed squared:

$H1/H2 = (N1/N2)^2$

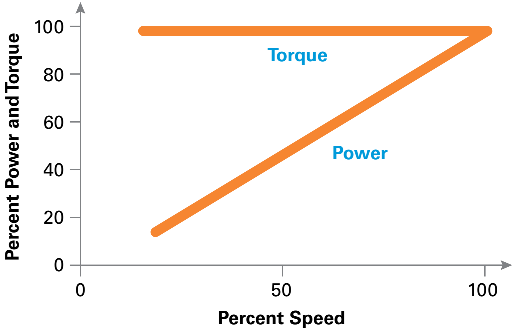
The change in power varies in proportion to the change in speed cubed:

$P1/P2 = (N1/N2)^3$

Where Q = volumetric flow, H = head (pressure), P = power, N = speed (rpm)

**The power – speed relationship** is also referred to as the ‘Cube Law’. When controlling the flow by reducing the speed of the fan or pump a relatively small speed change will result in a large reduction in power absorbed.

*Figure 4* *Constant Torque Load Profile*



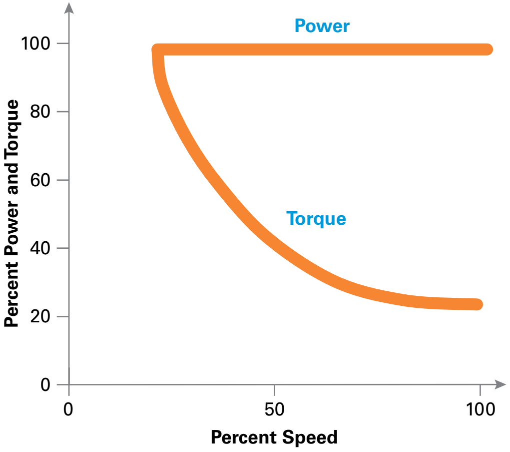
## 2. Constant torque load

Typical constant torque applications include conveyors, agitators, crushers, surface winders and positive displacement pumps and air compressors.

On constant torque loads the torque does not vary with speed and the power absorbed is directly proportional to the speed, this means that the power consumed will be in direct proportion to the useful work done, for example, a 50% speed reduction will result in 50% less power being consumed.

Although the potential energy savings from speed reduction are not as large as that with variable torque loads, they are still worth investigating as halving the speed can halve the energy consumed.

*Figure 5* *Constant Power Load Profile*



## 3. Constant power load

On constant power loads the power absorbed is constant whilst the torque is inversely proportional to the speed.

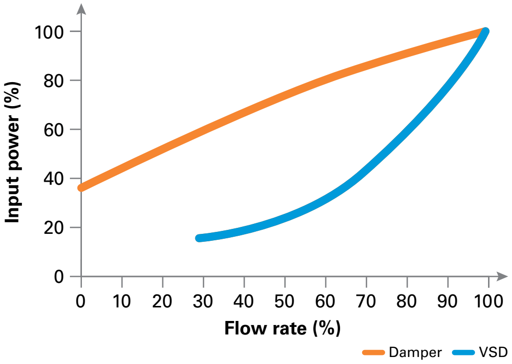
There are rarely any energy savings opportunities from a reduction in speed.

Examples of constant power applications include centre winders and machine tools.

# Fans

## Although dampers are often used to regulate the output of fans, reducing the speed of the fan is a much more energy efficient method of achieving the same effect.

*Figure 6* ***Fan power when flow regulated by damper vs. flow (speed)***



Note: When operating at near full speed there is a crossover point where VSD control can use more energy than fixed speed control with dampers. This is due to the losses in the VSD exceeding the savings from the speed reduction.

With damper control, the input power reduces as the flow rate decreases, however under VSD control the power reduction is far more dramatic. The variable torque characteristic of the fan means that the relationship between flow and the speed of the fan is such that the input power reduces in a cube law relationship with the speed reduction, as shown in the graph.

Variable speed fan control can be applied in a wide variety of applications including most kinds of ventilation systems, air extract systems, industrial cooling, and combustion-air control systems for boilers.

One of the limitations of VSDs is that it is not normally possible to reduce the flow all the way to zero due to a reduction of cooling capacity in the motor; a minimum speed of around 30% is permissible, however this is dependent on the specification of the VSD and motor.

In addition to reducing the power absorbed, VSDs in fan applications may also result in reduced noise in heating and ventilation ductwork due to the elimination of dampers. When regulating flow rates dampers can induce unwanted vortexes in the airflow which create noise and vibration. In a VSD system, making flow-rate changes generally only results in slight changes to the noise levels, which are normally undetectable to the ear.

**Fact:**

Reducing fan speed not only reduces energy consumption but may also reduce noise and vibration.

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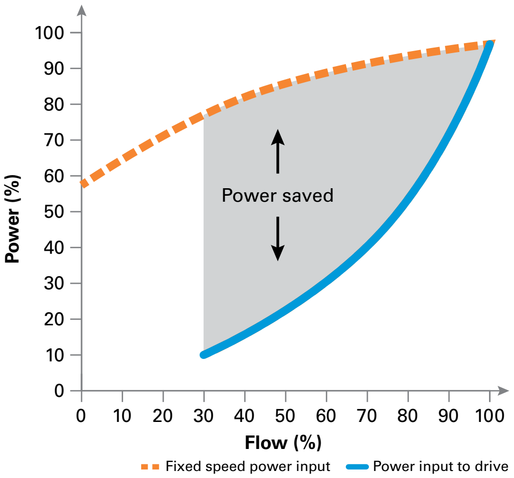
# Pumps

*Figure 7 Pump power saving when flow regulated by throttle valve vs. speed reduction*



Like fans, using a VSD to control the flow rate from a pump rather than using simple throttle control can result in large power – and therefore cost – savings. This is illustrated in Figure 6, where the broken line indicates the power input to a fixed-speed motor and the solid line indicates the power input to a VSD. The shaded area represents the power saved by using a VSD for a given flow.

Note: When operating at near full speed there is a crossover point where VSD control can use more energy than fixed speed control with a throttle. This is due to the losses in the VSD exceeding the savings from the speed reduction.

In a similar way to using damper control in fan applications, using throttle control for pumping applications results in a drop in pump efficiency, whereas the efficiency remains higher when the output is regulated by speed control. This is illustrated in Figure 7 on page 13.

The original fixed speed operating point (1480rpm) of the pump is at (Point 1) where the system curve intersects the head-flow profile at a flow rate of 700m$^3$/hr, the efficiency is circa. 85.1%. If the output is regulated by a throttle the system curve effectively moves to the left (Point 2) where the pump efficiency has declined to 78%. Conversely if the output is regulated by speed control the operating point moves down the system curve (Point 3) whilst the pump efficiency declines marginally.

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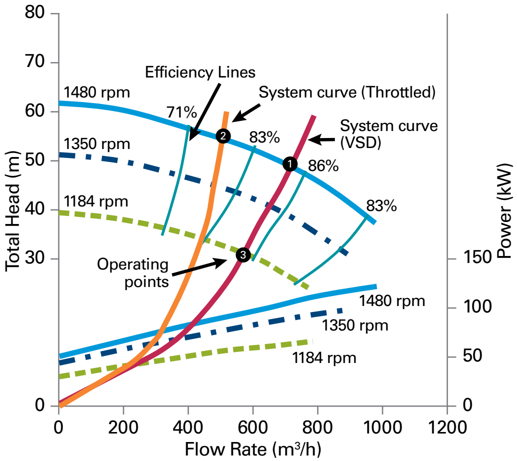
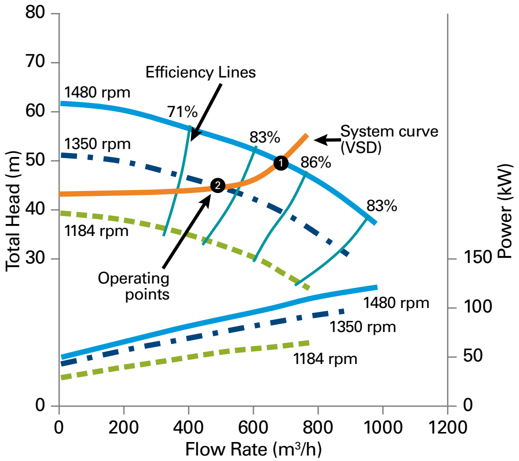
*Figure 8* ***Pump efficiency, throttle valve control vs. speed reduction***



On systems with a high static head, in particular pumping applications (see Figure 8) for example, boiler feed-water pumps or high lift applications, where the pump must overcome the resistance to lifting the water before any flow starts, the benefits of using VSDs will be reduced. This is because higher speeds need to be maintained in order to overcome the additional resistance due to the high static head. Factor this into any calculations (including Affinity Laws) and consult your pump supplier for further information on how to take account of static head.

*Figure 9* ***Effect of high static head on system head-flow curve***

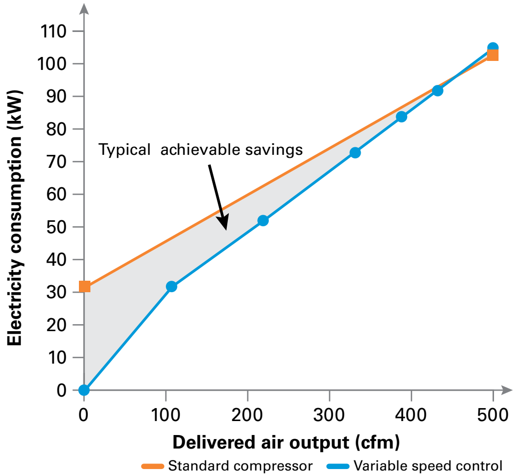


Typical examples of pump applications that will benefit from VSDs include circulating water in HVAC systems, boiler feed-water pumps, process pumps and other applications where flow demands vary.

## Air compressors

The potential for energy savings from using VSDs for air compressors will depend on the control system being replaced. The following diagram (Figure 8) illustrates the energy savings generated from fitting a VSD as compared to standard On-Off control.

*Figure 10* ***Energy savings due to VSDs on a typical air compressor***



Unlike fans and pumps most air compressors present a constant-torque load and have less scope for energy savings, nevertheless it can be economically viable to fit VSDs to air compressors where the average loading is 75% of capacity or less.

Some compressors are not compatible with VSD controls and could be damaged if so controlled; always consult the compressor manufacturer for advice when considering retrofitting a VSD.

Further information on fitting VSDs to air compressors can be found in our How to apply variable speed drives to air compressors (CTL052) guide.

## Top tip:

You can check if a compressor is lightly loaded by listening to the amount of time the compressor is on-load compared to the amount of time it is off-load during the course of the day. You will be able to hear the pitch change when the compressor is idling or off-load. If your compressor is off-load more than it is on-load, it may be appropriate to consult the compressor manufacturer or a VSD supplier to assess its suitability for either retrofitting a VSD, or buying a new, suitably sized VSD compressor.

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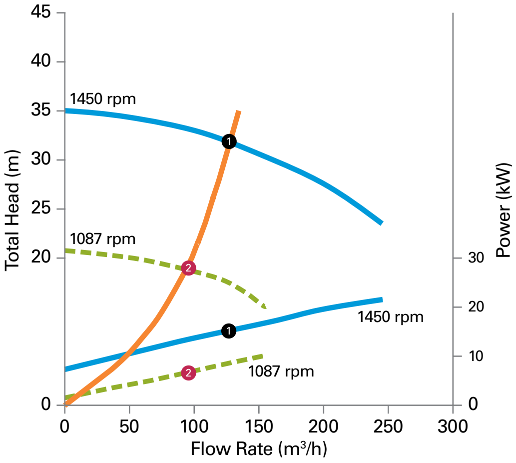
# Estimating savings from VSDs

The following demonstrates how to estimate the energy savings potential in a pumping system by reducing the speed (assuming little static head in the system). Refer to Figure 10:

*Figure 11* ***Adjusting pump duty by VSD control***



A fixed speed pump operates 6000 hours per annum at 1450rpm delivering $125m^3$/hr against a pressure head of 32m, and absorbs 15.1kW (Point 1). It is possible to reduce the flow demand by 25% for 60% of the operating time (Point 2). Calculate the associated energy saving potential, and the electrical cost savings given an electrical price of £0.08/kWh:

First apply the Affinity Laws to calculate the potential power reduction based on the change in flow from $125m^3$/hr to $93.75m^3$/hr as follows:

Calculate the speed (flow) reduction ratio:

$93.75m^3/hr/125m^3/hr = 0.75$

To calculate new operating head:

$(0.75)^2$ x 32m = 18m

To calculate power absorbed:

$(0.75)^3$ x 15.1 = 6.37kW

Now calculate the current consumption:

6,000 hours x 15.1kW = 90,600kWh

Then calculate the consumption at the different duties:

6,000 x 40% x 15.1kW = 36,240kWh

6,000 x 60% x 6.37kW = 22,932kWh

Calculate the annual savings potential:

90,600kWh – (36,240kWh + 22,932kWh) =31,428kWh

Calculate the electrical cost savings:

31,428kWh x £0.08 = £2,514 per annum.

# Other benefits of VSDs

## Variable speed drives are installed in a variety of applications and not just for their energy saving benefits. Other benefits include:

**Tighter control of the process:** In addition to enabling precise speed control of applications such as conveyors or winders, other parameters such as pressure, flow and even temperature may be accurately controlled.

**Programmable acceleration and deceleration:** Features such as soft starting reduce excessive stresses being placed on the motor and drive train, which can prolong equipment life. Soft starting also limits electrical currents at start-up, reducing motor heating and enabling more frequent starting, whilst limiting the demand on the mains electrical supply.

Dynamic braking can decelerate loads in a rapid and controlled manner.

**Improved power factor:** The efficiency of the electrical supply is increased and more of the electrical current drawn is used to drive the load.

**Good dynamic response:** Rapid adjustment of speed, torque and power gives better control in high speed applications. In some applications it is also possible to operate motors at higher speeds than their nominal speeds.

**Computing intelligence and communications:** It is possible to interface VSDs to wider process control systems such as supervisory control and data acquisition (SCADA) systems and building management systems (BMS).

**Controlling overhauling (braking) loads and regenerating power:** Options are available where the rectifier stage in the VSD is similar to the inverter stage and it is possible to return electrical energy recovered from electrical braking of the load to the mains supply. This is more energy efficient than using a braking resistor to dump the recovered energy; electrical cost savings can be achieved and in many overhauling applications it is cost effective to pay for the additional cost of the ‘active front end’ on the VSD. These designs also induce less harmonic interference on the electrical supply.

# Other types of variable speed controls

## Permanent magnet motors and drives

Permanent magnet motors have traditionally been used in precision speed applications and where high torque has been required such as paper and steel winders. The technology is more energy efficient than conventional AC induction motors and for this reason manufacturers are starting to offer it as an alternative in general purpose applications. Hybrid permanent magnet motors combine AC induction technology and permanent magnet technology and are offered as direct replacements for conventional AC induction motors. Other permanent magnet motors will only operate when connected to a dedicated VSD which has been optimised for their control.

## Reluctance motors and drives

These machines consist of a switched/synchronous reluctance motor and dedicated electronic controller. Their performance capabilities are similar to that of conventional induction motors and VSDs, in addition they are capable of very high-speed operation (up to 100,000rpm). Their energy efficiency performance can equal or better that of AC induction motors with VSDs. Like permanent magnet motors manufacturers are starting to offer them as an alternative to AC induction motors in general purpose applications due to their high efficiencies.

## DC drives

These machines consist of a Direct Current (DC) motor and dedicated electronic controller. They used to dominate the variable speed market prior to the advent of VSDs, however a niche market remains. Their efficiency is comparable with a conventional induction motor with a VSD.

Benefits of DC drives include:

They are capable of providing very high starting and accelerating torques and so may be more appropriate for applications such as starting up a mixer while it is full.

They are less complex than AC drives with a single power conversion from AC to DC.

DC regenerative options are available for applications requiring continuous regeneration for overhauling loads.

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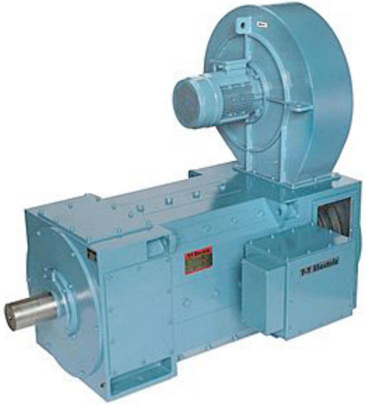
One disadvantage of DC drives is they tend to require more maintenance as the motors contain brushes and so they are better suited to lower speed operation where commutation is less of a problem.

They are still in use today mainly in specialist applications where high starting torques and variable speeds are required, such as pulsating loads, shears, bending rolls, plunger pumps, conveyors, elevators and crushers. Their price is comparable to AC induction motors with VSDs.

*Figure 12* ***Large DC motor with forced air cooling fan***



## Mechanical variable speed drives

These use mechanical means to convert a fixed-speed motor output into a variable speed output. This is typically achieved through the use of adjustable belt and pulley mechanisms or through metal roller mechanisms with adjustable diameters. These devices have inherent mechanical losses and so are not as energy efficient as electronic controls. Energy losses can be up to 20% higher than electronic controls.

## Hydraulic variable speed drives

These use hydraulic oil as a medium through which the torque is transmitted to the output; the output operates at a slower speed than the input and this is particularly useful for accelerating high torque loads. Their mechanical and hydraulic losses are relatively high and so are less energy efficient than electronic controls at reduced speeds.

# Practical considerations

## Selecting a variable speed drive

VSDs may be able to offer significant energy saving opportunities for specific applications. However, when considering purchasing and installing a VSD care must be taken to ensure that it is the correct solution and that it is properly applied in order to achieve optimum energy savings. This section provides guidance on issues to take into account when considering a VSD.

### What type of torque load will be controlled?

As mentioned previously, the largest energy savings can be achieved from variable-torque loads such as fans and pumps whose outputs have been regulated in some way. Refer to the earlier sections for information describing the types of load.

### Is a VSD necessary?

Overall, the most appropriate applications for VSDs are those where the output is less than 100% utilised by the process and is variable, examples include where the output of a pump or fan is regulated, cycled on/off, re-circulated or vented.

Some form of investigation may be required to determine the relationship between the capacity of the motor system and the actual requirements of the process; all monitoring should be conducted over a period of time.

In applications where a reduced output is required but which remains constant it may be more appropriate to install smaller fixed speed equipment.

Your equipment supplier will be able to advise on the best method of monitoring and estimating the potential savings, some offer a monitoring service, where they will monitor equipment for a period of time before recommending a particular solution.

**Did you know?**

Most fans and pumps are over sized for the duties they perform.

### Optimise the system to be controlled

Before selecting and installing a VSD, make sure that the system to be controlled is efficient and correctly sized. Look for areas of potential energy waste and implement corrective actions; examples include:

- Redundant legs in pipe-work/ducting.
- Leaks.
- Disused dampers, throttles and valves.
- Faulty control components such as valves or dampers.

Refer to the guide Motors & drives technology overview (CTV048) for guidance on minimising the demand and correctly sizing the system. It may be possible to reduce the size of the motor and other equipment being controlled, and lead to the purchase of a smaller VSD.

## What size of VSD is required?

The VSD is usually sized according to the size of the motor. In some circumstances such as at high altitude, warmer environments or where the supply voltage is low the VSD might need to be de-rated.

Consult your VSD supplier for guidance on sizing the VSD.

## What type of control is required?

It is possible to control VSDs manually however this approach is prone to human error and response times can be far too long. In the majority of applications VSDs are used as part of an automatic control loop; in a control loop, a transducer monitors the flow-rate or pressure and then a process controller (or the VSD) generates the correct speed-demand signal automatically. For example a pressure transducer will provide feedback that the controller will use to signal a speed change in the pump to maintain a constant pressure in a building where the water demand is variable. Another is the use of an oxygen sensor informing a control loop to regulate the speed of a fan to trim the oxygen levels in a boiler.

Control loops have the advantage of performing rapid corrections, minimising wastage and maximising the energy savings. The decision on the type of control required should be made in consultation with your equipment supplier.

## Electrical filters and cabling

VSDs can introduce electrical harmonics (a form of electrical pollution) on to the electrical supply which can be harmful to other equipment. There are regulations governing the permissible levels; to meet these requirements optional electrical filters may be fitted to the supply, or a different rectifier stage in the VSD may be selected.

Where VSDs are located some distance from the motor certain cabling restraints might apply; in all of these your VSD supplier will be able to provide suitable advice.

## Electric motor considerations

When fitting a VSD to a motor there are a number of considerations to take into account to ensure reliable operation, in all of these your VSD supplier will be able to provide suitable advice:

- **Older motors:** some older motor designs may not have sufficient electrical insulation in their windings to withstand high transient voltages that can occur with the use of VSDs. They should be checked to ensure their suitability for VSD controls.
- **Bearing currents:** in some applications mainly with large motors (90kW and higher) or where high switching frequencies are used there is a risk of stray electrical currents being induced in the motor which can cause damage to bearings.
- **Insulation breakdown:** very long cables runs, or high frequency switching can cause high transient voltages that may be damaging to winding insulation.

- **Motor cooling:** Motors operating under VSD control tend to run a little hotter than motors directly connected to the mains supply. When motors are operated at low speed their cooling fans loose effectiveness and alternative methods of cooling are required. Ensure adequate cooling is achieved; the threshold for additional cooling is specific to the installation. In some applications motors may be de-rated to ensure adequate cooling.

## Alternatives to VSDs

VSDs may not be appropriate or cost effective in all applications; there are alternative methods of control and they include the following:

### Sequential controllers

Where multiple fans, pumps or compressors are installed, sequential controllers can be used to sequentially start and stop equipment according to the process demands. Whilst not as precise as variable speed control significant energy savings can still be achieved.

### Changing transmission ratios

Where reducing the speed will produce savings, but it is not cost effective to install a VSD it may be possible to change the pulley ratio on belt-driven systems, or change gearbox ratios. These low cost speed-reduction methods can pay for themselves within a couple of months.

### Equipment changes

Changing fan impellers or trimming pump impellers are lower cost methods of reducing the output and achieving a better match of the fan or pump with the system demand. Paybacks can be realised within months.

## Limitations of VSDs

There are some limitations to using VSDs in relation to specific applications. These should be taken into account before making the decision to change to variable speed control.

No flow conditions: a VSD controlled pump cannot deliver the same function as a control valve at no flow or near zero flow conditions. A control valve can, and generally does, serve as a first line of defence as a shut-off valve and back-flow prevention. If a throttling valve is not used, the process designer will have to consider using an automated auxiliary valve on the pump discharge that will close when a no-flow condition is required.

High speed response: whilst VSDs offer dynamic response to changing operating conditions some specialist applications require a near instantaneous response to say flow rates, this can only be achieved through the use of a properly selected control valve.

Full load conditions: in well-optimised applications where the process demand may already closely match the full-load capacity of the motor, then use of a VSD with its associated energy losses would only add to the overall system losses.

Equipment speed limitations: some equipment is not designed to operate at reduced speeds, for example some air compressor types, and could be damaged if operated at a reduced speed. Check with equipment suppliers to ensure the equipment is compatible with variable speed operation.

## Commissioning a VSD

A VSD must be correctly installed and commissioned if it is to operate correctly and realise the intended energy savings. Unfortunately it in not uncommon to find installations where the motor operates continuously at full speed, yet no-one is aware. Look out for the following before, during and after the installation:

- The installer has been suitably trained and is competent to install VSDs.
- The intended process operating profile and control method are fully understood and communicated with the VSD installer prior to commencing the installation.
- The VSD is correctly programmed to deliver the intended operation (and energy savings) and that this is demonstrated to operators/ engineering staff on completion.
- Operators/engineering staff are trained in the control and operation of the VSD.
- A commissioning file containing records of software settings, set points and other relevant programme parameters is compiled and stored for future reference.

## The importance of maintenance

Once a VSD has been installed, energy savings can be maintained or improved further by carrying out regular maintenance.

Contrary to the common belief that electronic equipment does not require regular maintenance, it is crucial for keeping VSDs at peak efficiency. Common reasons for energy wastage on poorly maintained drives are:

- A demanding environment, such as high ambient temperatures or a heavy load, which measurably reduces the life of the drive components.
- Setting incorrect parameters, resulting in poor control and energy wastage.
- Insufficient cooling, which leads to increased energy use. An increase in heat will increase electrical resistance, automatically causing the current to increase to compensate. This increased current equates to increased power consumption. Overheating drives can lead to equipment failure.
- Contamination ingress (from materials such as water or dust) causing inefficiencies and equipment failure.
- Loose electrical terminals leading to overheating and failure.

Production standstills or equipment breakdowns invariably entail cost, so a systematic VSD and equipment maintenance plan is recommended to reduce the possibility of equipment failure. Preventive maintenance is always less expensive than correcting faults and having unanticipated breakdowns.

The drive manufacturer might also recommend a schedule for replacing parts, for example, an annual air-filter replacement or a four-yearly replacement of any cooling- pump seals. A good way to ensure a VSD is kept in optimum condition is to enter into a maintenance contract with the drive manufacturer.

**Fact:**

VSDs are not as expensive as you might think. Fitting one to an average motor can cost around £650 – including installation. When you consider that a single, average (2.2KW) motor can consume over £500 worth of electricity in a year, a VSD is well worth the investment and can have a payback period of less than two years.

MENU

# Next steps

## There are many easy low and no-cost measures to help save money and improve the operation of electric motor driven systems.

The following suggests actions to take when considering installing a VSD.

**Step 1:** Develop an understanding of the process in question and how the operation of the motor system meets its requirements. Determine to what extent the demand is variable and whether the demand can be reduced.

Document the load profile and establish by how much it can be reduced.

**Step 2:** Determine the load type, whether it is variable torque, constant torque or constant power.

Establish whether VSD control can be implemented on the system or if another solution will be more appropriate.

**Step 3:** Look for opportunities to maximise the existing system efficiency through low cost measures. There is little benefit in fitting a VSD to a system which suffers poor efficiency that could be improved by other low cost means. Assess the condition and operation of the system and identify low cost energy savings opportunities that could be implemented prior to fitting a VSD. These could include maintaining equipment, or reducing demand and switching off. Some of these improvements may be implemented through actions taken in-house, whilst other actions may require specialist support from a supplier or consultant.

**Step 4:** Monitor existing energy consumption and estimate the energy saving potential. If possible, monitor the power consumption over, say, one week to gain a baseline against which any improvements in energy efficiency can be measured. Seek expert help where necessary.

Obtain quotations from suppliers and ensure the savings and payback on investment are satisfactory.

**Step 5:** Having taken into account the points described in ‘Practical Considerations’ install the VSD and associated controls. Ensure the installer is fully briefed prior to commencing work, and that the system is properly commissioned and savings are demonstrated prior to sign off.

**Step 6:** Continue to manage your systems for energy efficiency.

Put in place policies, systems and procedures to ensure that systems are correctly serviced and operating efficiently and that savings are maintained in the future.

HELP

# Glossary

**Adjustable speed drive**
An alternative name for a VSD.

**Commutation**
A term that refers to the action of directing currents or voltages to the proper motor phases so as to produce optimum motor torque. In brush type motors, commutation is done electromechanically via the brushes and commutator. In brushless motors, commutation is done by the switching electronics using rotor position information obtained by Hall sensors or resolver.

**Control unit**
Part of the VSD with computing intelligence; it receives from, and sends signals to the rectifier, the intermediate circuit and the inverter to correctly operate the equipment.

**Damper**
Typically a mechanical device which restricts the air flow in the ducting of an air movement application.

**Drive train**
The combined equipment that delivers mechanical power to the equipment being operated, typically the electric motor and mechanical power transmission components.

**Dynamic braking**
Braking that can be enacted while the motor is in motion.

**Dynamic response**
A response that can be enacted while the motor is in motion.

**Frequency converter**
An alternative name for a VSD.

**High-reliability check valves**
A highly reliable non-return valve.

**Induction motor**
A motor that uses electrical induction to produce torque.

**Intermediate circuit**
Part of the VSD that conditions the rectified DC supply, normally by a combination of inductors and capacitors.

**Inverter**
Part of the VSD that converts the rectified and conditioned DC supply back into an AC supply of variable frequency and voltage. This is normally achieved with a semiconductor switch.

The term is also a commonly used to refer to an entire VSD.

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**Load**
The equipment that is being driven by the motor.

**Power factor**
A measurement of the phase difference between the voltage and current in an AC circuit. Power factor is the ratio of real power (kW) to total reactive power kVA or the ratio of actual power (watts) to apparent power (volt-amperes).

**Rectifier**
The part of a VSD that changes the incoming AC supply to DC.

**Soft starter**
A device that regulates the amount of starting current supplied to the motor. This makes for a smooth mechanical start.

**Speed-demand signal**
This is the feedback given to the motor-speed control device, indicating what speed the motor should be running at.

**Static head**
The fixed pressure resistance in a circuit that must be overcome to deliver a fluid. For example the difference in height when pumping from a supply to a destination reservoir, or the pressure to overcome when filling a pressurised vessel.

**System losses**
The losses inherent in any system. For example, friction losses in a system of ductwork.

**Throttle**
A device used to reduce flow in a fluid-movement application. For example, a butterfly valve.

**Torque**
The amount of rotary force applied to/by a rotating shaft.

HELP

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- opening markets for low carbon technologies
- leading industry collaborations to commercialise technologies
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The Carbon Trust receives funding from Government including the Department of Energy and Climate Change, the Department for Transport, the Scottish Government, the Welsh Assembly Government and Invest Northern Ireland.

The Carbon Trust is a company limited by guarantee and registered in England and Wales under Company number 4190230
with its Registered Office at: 6th Floor, 5 New Street Square, London EC4A 3BF.

Published in the UK: November 2011.

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