Guide to Variable Speed Drives (VSD)

Why using a VSD can help you save money and the environment

Motores | Automação | Energia | Transmissão & Distribuição | Tintas

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1. Top three reasons to select a VSD

1. Importance to industry

One of industry's principal concerns with soft starters is the limited slow speed control they demonstrate between starting and stopping. In contrast, a VSD) can deliver precise speed control, including during start-up and stopping. In short, VSDs provide continuous and completely adjustable speed whenever required, from starting to stopping, for hours at a time.

Starting and stopping are big issues in the motor control arena. As their name implies, soft starters provide a gradual ramp up to full speed and are used only at start-up (and stop, if equipped). If speed variation control during operation isn't required, soft starters provide an affordable solution. VSDs, in contrast, offer additional versatility and are completely adjustable control across the entire running cycle.

Torque is another issue. Typically, soft starters function using a fixed frequency, with full torque only accessible at full voltage. Furthermore, full torque is unavailable at zero speed, as the associated voltage for the torque setting is the starting point of the ramp.

In comparison, full torque can be offered up to line frequency at base motor speed for VSD applications. In fact, the ability to hold torque levels is a benefit offered by VSDs in certain safety applications for a prevention of an unexpected startup of machinery or for an emergency stop where there is no active load affecting the motor, whereas using a soft starter in this way would require an additional device, such as a mechanical brake.

Soft starters also provide an economic advantage in instances which require torque control only during motor start-up.

2. When energy consumption must be minimised

Energy savings are a headline benefit of VSDs, and the explanation for this characteristic lies with speed control. In applications where traditional belts or gearboxes are used to lower speed, the motor still runs at full speed. Conversely, using
a VSD in the same way serves to actually reduce the motor speed. The upshot of this effect is that fewer amps are drawn by the motor. In turn, there is less energy consumption, resulting in lower energy bills.

Arguably the most notable energy savings will be experienced in applications such as fans, pumps and compressors, as loads increase with speed when running such devices. Using a VSD to adjust the flow rate of fans and pumps has a significant impact on the flow curve, which has the knock-on effect of lowering the required power.

Almost all fans and most pump types are variable- torque loads, whereby the torque will in fact increase with the square of the speed. As a result, power is proportional to the cube of the speed.

To give a tangible idea of savings, lowering the running speed of a fan or pump by a modest 10% could reduce power consumption by a worthwhile 25%. The good news is that the savings continue to multiply in proportion. So, using a VSD to reduce running speed by 20% will likely bring in savings of around 50%. With energy savings like this on offer, the period required for return-on- investment (ROI) shortens, making the adoption of VSD technology increasingly attractive.

3. When maintenance costs need to be reduced

Another major advantage associated with the use of VSDs is that gradual acceleration of the motor from standstill promotes extended service life and reduced maintenance costs. In comparison, if not using a VSD, the motor will start instantly with a large current, which can be highly detrimental to motor longevity.

Controlled starting current is vital. Starting an AC motor ‘across the line’, as it is commonly known, can take up to eight times the full load current. Such a surge can actually cause the motor winding to flex and produce heat, leading to a potential compromise in the useful working life of the motor. In simpler terms, an AC motor started across the line creates greater mechanical shock loads for both the motor and load. What’s more, this shock occurs every time the motor is started. It follows, therefore, that the premature wear of motor components will be virtually inevitable.

A VSD, on the other hand, starts at zero speed and accelerates smoothly on a ramp that is fully adjustable by the user. To provide more detail, VSDs start a motor at zero frequency and voltage and, as these parameters rise, the motor windings become magnetised, which requires up to 70% of the motor’s full load current. The benefits of this more gentle’ approach include extended motor life, reducing both maintenance and replacement costs for the end user.

It is also worth noting that controlled stopping is considered just as important as ramped acceleration in terms of minimising potential motor wear, along with any consequential downtime of the load and associated costs.

However, soft starters are often the ideal solution for applications where space is a concern as they usually take up less space than VSDs.

2. Why VSDs are best for fans

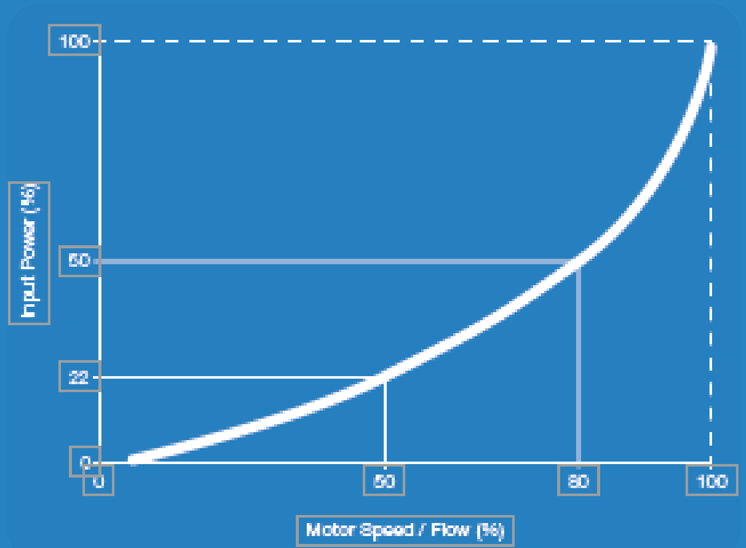
1. Energy savings

The energy efficiency of VSDs is a common benefit across many motor applications, not least fans. It is well documented that air-handling equipment is capable of consuming large amounts of energy. Therefore, any discerning production or plant manager will want to give careful thought to energy management.

The cube law relationship described in Chapter 1 – power is proportional to the cube of the speed – applies here. This relationship compares extremely favourably with a traditional form of fan speed control, such as a damper. Although with a damper the input power reduces in line with flow rate, using a VSD produces a far more dramatic reduction.
This effect is good news for a whole host of fan-based applications, including air extraction and ventilation systems, as well as industrial cooling and combustion-type air-control systems commonly found in boilers.

2. Reduced wear

Such are the energy savings that can be accrued from the adoption of a VSD in fan applications that the reduction in electricity consumption alone can often justify the purchase. However, there are additional savings that can be achieved through reduced mechanical wear and associated maintenance. In addition, the power ‘demand charge’ is reduced as the motor can be started without any surge in current.

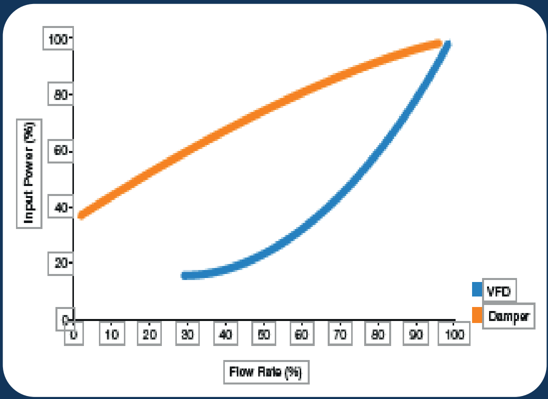


3. Improved power factor

By definition, power factor is a measurement of reactive power – namely the VA used to establish the motor's magnetic field. In more basic terms, power factor is essentially a measure of how effectively a piece of equipment, such as a fan, uses electricity to produce useful work.

Most fans are driven by AC induction motors, which are well known to have comparatively low power factors, even when performing at maximum capacity. Furthermore, when AC induction motors are only lightly loaded, the power factor falls even lower, sometimes close to zero.

The best way to improve this power factor is to apply a VSD. As a VSD does not create any major displacement of voltage or current waveforms
(it remains almost perfectly in phase), it can be thought to have a power factor of close to unity
(power factor = 1.0).



4. Better than using dampers

While dampers are a common device for controlling fan output, reducing speed using a VSD is a far more energy-efficient way of achieving the same outcome. Despite this disparity in efficiency performance, however, there are a number of factors that should still be given consideration before choosing between a damper and a VSD in a fan application. For instance, how many hours is the fan likely to be working, and how expensive is energy in the country of installation? A fan that only runs occasionally, in a country with low energy prices, might only require a damper.

Another issue is purchase cost. Sure enough, dampers will in general come with a more attractive price tag, but when considering the impressive energy-saving capabilities of VSDs, the long-term total cost of ownership (TCO) will far outweigh any initial purchase cost savings. By way of example, many will opt for a VSD with motors above, say 35 kW, as the reduction in energy consumption easily offsets the acquisition costs. However, today's VSDs are increasingly used with much smaller motors, too.

Replacing dampers with VSDs in fan applications has additional benefits worthy of note, not least reduced noise in heating and ventilation ducting. It is well documented that using dampers to regulate fan flow rates can generate undesirable vortexes in air flow, which in turn produces vibration and noise. The same phenomenon does not occur with VSDs, where flow rate adjustments produce fluctuations in noise levels so slight they are undetectable by human ears.

3. Five reasons to select VSDs for pump applications

1. Better than on-off controlled pumps

For some seeking a low-price-tag solution to pump control, an on–off pump will feature little more than a pressure switch, bladder tank and flow switch. A bladder tank is required to avert any potential issues that arise from pressure peaks and troughs, such as damaged pipework.

As the name suggests, this pump type's main limitation is that it only offers two speeds: maximum or stopped. Starting up from standstill can have a number of problematic effects, including premature wear to pump seals and bearings, as well as excessive stress on the motor's winding, which can consequently prompt premature failure.

Instead, most pump users opt for either a VSD or soft starter. While the latter can reduce known effects such as water hammering due to pressure surge, a drive can deliver the same outcome, but with the added advantage of providing complete pump speed control during run mode.

2. Improved efficiency

In common industrial systems such as centrifugal pumps, in-line control (throttling) valves are sometimes deployed to regulate flow or pressure. However, there is a significant drawback with using such a device. In short, in-line valves are known to be a notable source of energy loss, primarily because they inherently cause a flow path restriction that in turn elevates pressure.

Conversely, a VSD is able to offer far more efficient flow control simply by altering the pump motor speed in line with requirements. Rather than changing the system resistance to modulate flow, as is the case with a throttling valve, the use of a VSD sees the pump speed change. In simple terms, variable-speed control alters the energy input rather than relying on a valve to strip system energy. Dramatic savings in electricity consumption are the common outcome.

3. Enhanced flow and pressure control

The use of a VSD to control flow means no additional restriction is added to the piping, as is the case with a throttling valve. Beyond the aforementioned energy savings, improved response means better flow control. Accidental emissions from the throttling valve are also eliminated.

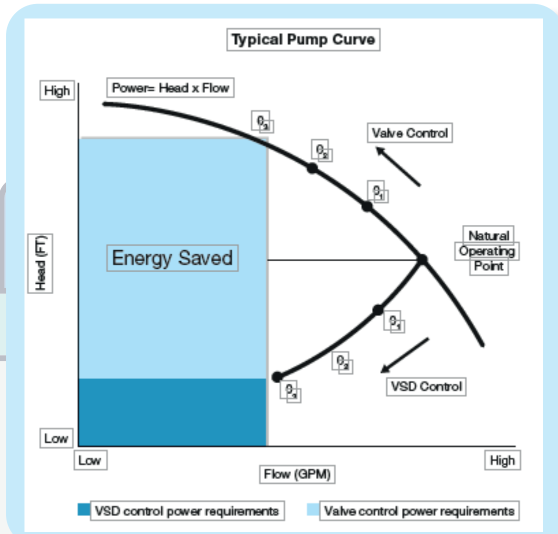
For pump systems where the flow demand often drops, throttling valves have further limitations. In such situations, this type of valve will often function at lower throttle positions, thus wasting even more energy through a greater pressure drop across the valve.

4. Eliminate the need for systems elements

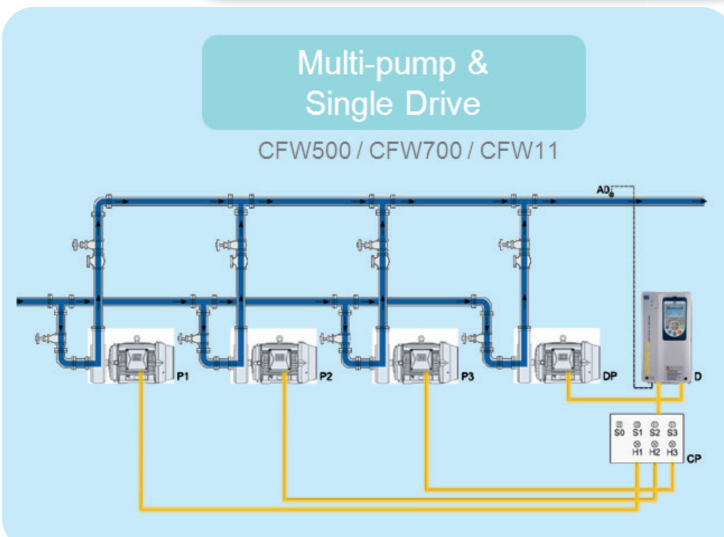
Opting for a VSD over an inline valve will present users with the opportunity to eliminate various system elements without impacting on functionality. When using a throttling valve, a certain amount of pipework is required to position the valve where it can be accessed for adjustment. Compare this with a VSD and the difference is plain to see: no valve, no need for associated pipework, and no losses from the valve or pipework.

There is another benefit here. Thanks to the removal of pipe and valve losses, there is the option to use a lower-power, less expensive pump. The upshot is that the cost justification for the VSD becomes even more attractive.

5. More intelligence



The latest microprocessor-based, modular VSDs have the capability to carry out multiple functions that at one time had to be performed by PLCs. Modern drives allow each module or process to operate almost autonomously, while at the same time integrating with the overall production line for sequencing industry 4.0 data and safety functions via open yet secure communication networks.
In addition, having an intelligent motion controller embedded in each networked drive represents a more cost-effective solution than employing a standalone PLC. A further disadvantage with a PLC-based system is that high-performance networks are required to handle the necessary motion control. In-stead, by letting an intelligent drive do the work, con-trol is given to the actual elements being run, thus enhancing performance. For example, the Pump Genius process control software is a customisable feature of WEG VSDs which manages and monitors up to 6 pumps in a coordinated system. Designed to minimise downtime and maximise energy savings, the software provides control and protection as well as management of cycle hours and master and slave designation. It also monitors and controls system pressure and flow with available faults and alarms referencing low and high set points.



4. Why VSDs are the only choice for HVAC applications

1. Optimal capacity modulation

Variable speed drives are connected to more motors than ever in heating, ventilation and air- conditioning (HVAC) systems because they can provide significant energy savings. HVAC systems are designed to function at peak load, even though this requirement only occurs for a relatively short period of time in any given year. As a result, one of the most effective ways to improve the energy efficiency of a HVAC system is to make use of a VSD. The VSD can be deployed to vary the speed of one or more motors based on load requirements. Dramatic cuts in energy consumption can be achieved.

2. Precise levels of control

The use of VSDs for HVAC applications provides more precise levels of control. A system utilising a VSD can exert more precise control over a wider range of flow rates and output, while simultaneously reducing energy requirements and pump wear. For example, a pressure sensor placed inside of an air duct can provide feedback to a drive (Proportional- integral-derivative) PID regulator, comparing desired pressure with actual pressure and delivering optimisation by adjusting the fan-motor speed. Besides a heating, cooling, and ventilation air- handling unit (AHU), proportional control can also be applied to cooling tower fans and chilled-water pumps.

3. One VSD to control multiple motors

A VSD can be used to control multiple motors in some HVAC configurations. The only caveat is that the correct design considerations are applied, particularly with regard to implementing sufficient overload protection for each individual motor. This stipulation is necessary because a VSD can only detect the total connected load and not which individual motor is drawing high current. It should also be noted that not every variant of overload protection device can be applied at the VSD output. Sizing the VSD appropriately is a further requirement.

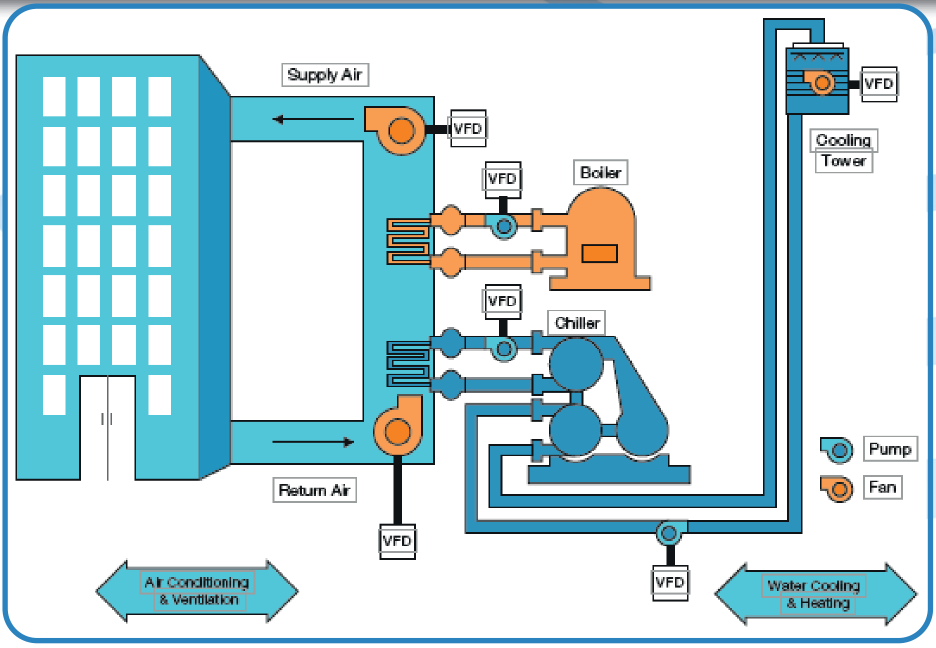
If these prerequisites can be met, using a single VSD to control multiple motors brings several benefits beyond simple cost savings. To provide an indication, control complexity can be reduced, as can panel space.

4. Network monitoring

If networking capabilities are required for the HVAC system, VSDs are a good choice. The only requirement is the inclusion of a suitable communications card for BACnet, Modbus or any other proprietary network. Having this capability means VSDs can communicate a diverse range of data on factors like system energy consumption, equipment health and diagnostics. Power and energy consumption data points are available through most modern VSDs. A major requirement for buildings featuring HVAC systems is having knowledge of where power is being used, so monitoring this type of parameter will allow plantroom staff to collect this data, and trend it accordingly.

For example, monitoring the energy consumption of an air-handling unit (AHU) within an office area or conference room might show differences in usage on a month-to-month basis. There could be several underlying reasons behind this fluctuating data, including outdoor temperature changes, increased occupancy or the AHU filters beginning to load, which in turn heightens pressure on the fan.

With monitoring, staff will be able to map out certain trends and impart better system maintenance to optimise energy efficiency and reduce bills. This type of activity will also help identify root causes in the event of HVAC system failure. With a networked VSD, scores of discrete alarms can be monitored, logged and trended, so that staff gain a comprehensive history of events. Having this invaluable information resource also helps the maintenance team return the HVAC system to its full operational state as quickly as possible.
There is much, much more data available over the network interface to the latest HVAC VSDs. These extend from straightforward monitoring points, perhaps of voltage or current, to high- level analysis points that could include power factor or harmonics.



5. A trio of justifications for using VSDs in compressors

1. Less energy use

Typically, a fifth of an average factory's electricity bill can be attributed to the production of com-pressed air. With almost all modern manufacturing and process plants looking to cut the cost of over-heads, the use of a VSD compressor in place of an existing rotary screw or piston-based machine can generate significant savings.

In short, the major benefit of using a VSD in these applications is that it automatically adjusts its mo-tor speed to the air demand. Estimates vary, but in terms of energy savings, using a VSD compressor in comparison to a fixed-speed, idling or load/unload compressor, could comfortably produce energy savings of 35-50%.

As a point of note, around 70% of a compressor's total cost of ownership (TCO), whether it is used for compressed air generation or refrigeration, can be attributed to energy consumption. So, while many look simply at the price tag of a compressor, this is in actual fact a false economy. Put simply, the initial cost of investment does not compare with the cost of energy over the lifecycle of the product.

2. Safety and reliability

Modern VSDs offer numerous safety features, like protection against power surges and short circuits, as well as STO (safety torque off) function-ality. By adopting a drive offering such features, compressor OEMs can avoid the requirement for certain electrical components that include motor circuit breakers and contactors, thus reducing costs. This strategy also boosts system reliability for the end user (fewer components to potentially fail) and, in turn, reduces the risk of system downtime.

3. More stable pressure

A VSD in a compressor system can stabilise the up and down pressure in the pipe network, potentially even eliminating pressure fluctuations altogether.
The upshot of this capability is that all compressors operating in the system can run at the lowest pressure needed to meet production requirements, and reduce the power loss caused by the fluctuation of upward pressure. Additionally, the potential for system leaks is minimised thanks to the lower system pressure.

6. Three digital trends

1. Communications

Nearly all VSDs have integrated serial comms as standard. In layperson's terms, serial comms involve transmitting a number of digital pulses to a VSD, which will interpret them, carry out the command(s) and perhaps return a signal. Clearly, suitable hardware needs to be defined, as does the communications protocol to avoid any signal mix-ups. A certain amount of verification will also be required.

Hardware usually boils down to wireless technology or fibre-optic cables. As regards signal protocols, a extensive number are available, with the type of application usually steering the final decision. Ethernet is a case in point – much of the automation industry is quickly transitioning to Ethernet as its preferred communications standard.

VSDs that provide Ethernet connectivity as a standard feature are increasingly found in factory automation applications, like those within the automotive and food processing sectors, as well as wastewater treatment facilities. Such VSDs can also connect to a manufacturing execution system (MES) network and exchange data in both directions. Ultimately, a configuration like this creates a gateway to other connected automation equipment throughout
the plant.

Also for consideration is the extent of common open fieldbus systems available, which include PROFIBUS, CAN bus, DeviceNet, BACnet and Modbus – most of which have Ethernet variants. Fieldbus systems are widespread across industry and are continuing to grow, but industrial Ethernet is arguably growing even more quickly.

2. Industry 4.0

With many manufacturers seeking a transition to smart factories, among the defining factors is the integration of intelligent motor control systems. Many of the latest VSDs come with embedded logic in the form of an on-board PLC, making it not only possible to monitor drives over a network, but to execute programs. The cost comparison is also favourable, with intelligent VSDs offering an inexpensive way to bring the latest Industry 4.0 technology on board and help grow the business.

Many productivity benefits are available, such as greater operational efficiency and quality control, as well as smart machine optimisation, remote/wireless diagnostics and predictive maintenance.

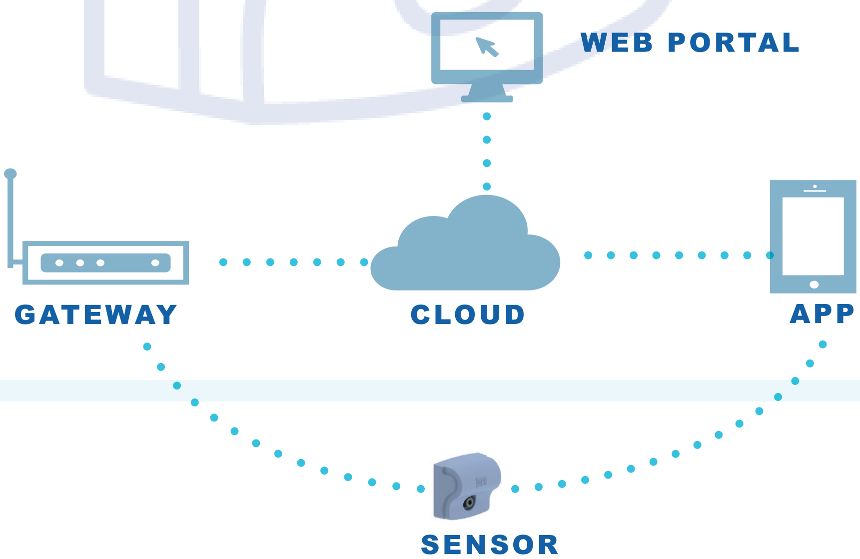
3. Wireless diagnostics

Wireless diagnostics represents the way ahead for VSDs, be it via Wi-Fi, Bluetooth or some other wireless technology. This capability is good news for maintenance teams, where access to an enclosure can often be limited due to its location or use within a plant. As a result, Engineers are able to connect directly to the system remotely using the drive's integral wireless signal. Once connected, the maintenance team can view and diagnose the issue without any physical contact with the drive whatsoever. If the wireless diagnostics data is trended, then this information can be used to support predictive maintenance strategies, for example.

A number of today's VSDs feature a web server that can monitor application continuity with time-stamped motor or drive-specific data. Moreover, any motor or drive data can be shared with a master PLC should an application fault occur. In fact, VSDs can provide a wide variety of data, such as motor current, motor torque, motor thermal state, drive thermal state, and bus voltage when the actual fault occurred.

Having data of this nature at their fingertips means that maintenance technicians can perform detailed root-cause analysis. Using the information collected, suitable alarms or warnings can be triggered should application data exceed a pre-determined limit. If required, this strategy could also be used to stop the application, quelling any potential problem before unwanted downtime results.

Consider a fan as a practical example. Latest- generation VSDs feature algorithms that can monitor the performance of wear components such as fans, and predict their service life using data that includes temperature, operational speed and total running hours. The maintenance team can exploit this information to repair or replace the fan accordingly, even planning work to take place during a scheduled shutdown period.



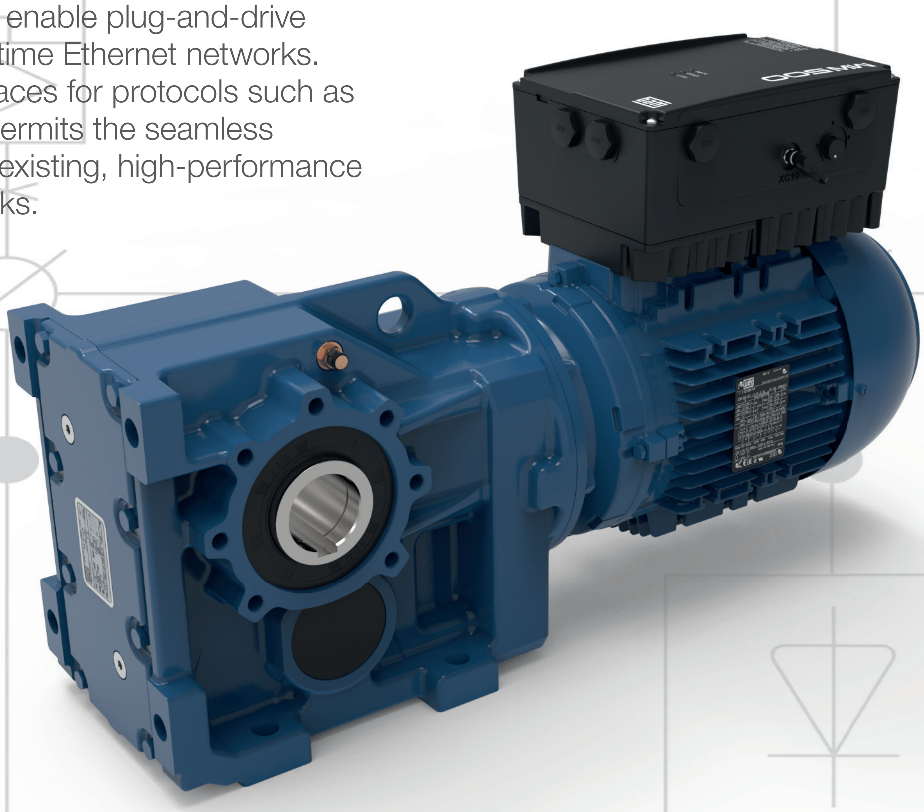
7. Benefits of decentralised drives

Decentralised VSDs are popular in applications where greater flexibility is required. Such drives do not require a panel or enclosure, allowing them to be mounted close to the motor and eliminating the need for long cables. The latest decentralised drives offer embedded features and a high degree of IP66/NEMA 4X protection to facilitate installation directly on the motor or a nearby wall. The rugged nature of decentralised drives not only protects against penetration by dust or jets of water, but provides complete protection for technicians and other plant personnel against contact with internal live parts. Further advantages include reduced installation costs and easy commissioning.

1. Networking capabilities

Today's decentralised VSDs offer optional communications networking and I/O modules that are fast and easy to install, allowing adaptation of the standard drive to individual user applications. Indeed, the availability of a large number of communications interfaces and the potential for flexible adaption makes decentralised VSDs suitable for many uses.

Many of the latest VSDs enable plug-and-drive communication via real-time Ethernet networks. The use of plug-in interfaces for protocols such as Profinet and EtherCAT permits the seamless integration of VSDs into existing, high-performance communications networks.



2. Integrated PLC

Built-in PLCs allowing the VSD, motor and application to work in an interactive way permit the user to implement customised logic and applications. Having an integrated PLC not only reduces load on the higher-level controller, it also lowers the investment needed for control cabinet installation and wiring, thus cutting system costs for the user. Furthermore, decentralised VSDs simplify system maintenance, giving overall plant efficiency a boost.

The specific features of the latest VSDs obviously vary between manufacturers, but some offer a number of useful functions. Flying-start capability is a good example, as it allows a motor to be started that was running freely, accelerating it from the speed at which it was running. Ride-through is another example, which keeps the VSD in operation during voltage dips. Typical applications for decentralised drives include pumps, mixers/ bottlers, conveyor belts, compressors, fans and washers/dryers, to name but a few.

Decentralisation can of course occur on many different levels, from a motor starter or drive located at the motor, to an entire decentralised system, which may comprise, for example, a VSD, overload protection, motor disconnect switch, I/O and bus module. If preferred, all of this can be provided as part of a single package.

3. Deliverable benefits when using decentrallised VSDs

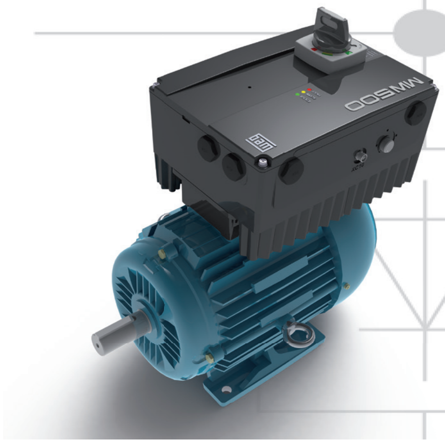
1. **Investment costs:** Savings are always application dependent, but potentially 30% or more could be saved against the comparable cost of centralised solution, which would entail more engineering time, more components and wiring, larger panels and PLCs, and slower installation and commissioning.

2. **Efficiency:** All the reduced energy consumption benefits of VSDs can be provided in a decentralised format.

3. **Flexibility:** Users can freely configure decentralised VSDs for deployment in a multitude of different applications.

4. **Compatibility:** Via connection to common bus systems and Ethernet, the latest decentralised drives can be integratedwith most types of automation system.

5. **Compact footprint:** VSD footprint is significantly less than that required for a centralised system, a factor supported
by heat-dissipating ability.



8. Miniturisation and micro/mini VSDs

NEMA 12 (IP54) and NEMA 4/4X (IP66) VSDs are increasingly popular in fan and pump applications. Today controls reside in the drive's software rather than external logic, meaning they are notably smaller and lighter. Such VSDs also reduce the overall number of components by minimising the need for wires, terminal blocks and additional cooling.

Modern micro and mini drives are not only extremely compact, but they are also highly flexible, meeting the requirements of a great variety of small-machine applications due to their high performance levels and easy integration. Even some of the smallest VSDs on the market still offer a power range of up to 4 kW, for example.

Flexibility is assured thanks to a wide range of functions and accessories, in addition to plug-and-play capabilities. Further features of today's micro and mini drives include the availability of single and three-phase variants, scalar control (V/F), current overload capacity (often up to 150%), DSP-controlled PWM output, up to four isolated programmable digital inputs, and programmable relay output.

Despite their size, many micro and mini drives feature integrated keypads and can display read-ings that include motor speed, frequency, voltage, current, last fault, heatsink temperature and drive status.Applications are wide and varied, extending from pumps, fans, extruding machines and dryers, through to rotating filters, cutting machines and conveyors.

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For those countries where there is not a WEG own operation, find our local distributor at www.weg.net.

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