Variable Speed Drives:
Reducing energy costs, improving competitiveness.

Factsheet

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Electric motors and their associated systems account for between 14 and 15% of South Africa’s energy consumption in the commercial and industrial sectors.

Extremely versatile and potentially the most underutilised solution for optimising the energy efficiency on a wide range of equipment - from motors, pumps, fans, conveyors and any compressor with a force feed oil system to Heating, Ventilation and Air Conditioning (HVAC) systems - using VSDs appropriately in any variable load application can save energy, cut operating and maintenance costs and extend the lifespan of equipment.

What is a VSD?

A VSD - also known as a Variable Frequency or Adjustable Speed Drive - is a device that can adjust electricity supply and regulate motor speed to match the actual demand required by the system or application it is driving, resulting in a reduction in energy consumption.

VSDs offer a high degree of motor control, accurately varying motor speed according to demand whilst adjusting torque accordingly – all within the specifications of a particular manufacturer.

A basic VSD can be used for simple applications, like controlling a pump or a fan where variable loads are required. It can also be interfaced with a transducer, such as a pressure or flow rate sensor, and programmed to maintain a particular setting. More advanced VSDs can be used for precise speed and torque control in complex applications like materials forming and can be interfaced with a computing system to provide real-time operating data on the status and performance of a motor.

The two figures below illustrate examples of applications ideal for using VSDs to improve energy efficiency - in Figure 1, much of the required flow is well below 100% capacity whereas, in Figure 2, the required flow is above 80% capacity.
Sizes, aesthetics and efficiency

VSDs come in many different sizes to suit a variety of applications and can vary from 0.18 kilowatts (kW) to several megawatts (MW), depending on the size of the motor. Typically, they are available as stand-alone devices connected between the electrical supply and the motor. They can, however, also be built onto a motor as an integrated motor drive product for small motors under 15kW.

VSDs are between 92 and 98% efficient with marginal losses resulting from additional heat dissipation caused by high frequency electrical switching.

**Slowing down a pump or fan from 100 to 80% can reduce a motor’s energy usage by up to 50%**.

How do they work?

All VSDs work on the same principle: They convert incoming electricity, which is on a fixed frequency and voltage, into a variable frequency and voltage.

When a VSD starts a motor, it initially applies a low frequency and voltage, typically 2Hz or less, which avoids the high starting current that occurs when a motor is started using a direct-on-line or star-delta starter method. The applied frequency and voltage are increased at a controlled rate to increase the speed of the motor (load) without excessive current being drawn.

Components of a VSD

1. Rectifier - it changes the incoming Alternating Current (AC) to Direct Current (DC) and also controls the direction of the power flow.
2. Intermediate circuit - it conditions the rectified DC supply, usually by a combination of inductors and capacitors.
3. Inverter - it converts the rectified and conditioned DC back into an AC supply of variable frequency and voltage; semi-conductor switches are used to create the output to the motor.
4. Control unit - it controls the operation of the VSD and also monitors and controls the rectifier, the intermediate circuit and the inverter to deliver the correct output in response to an external control signal.

Drives adjust the speed of electric motors to match the actual demand of the application, thereby reducing motor energy consumption typically by 20 to 50%.

How do VSDs save?

VSDs save energy because they prevent motors from using more electricity than required - many motors are oversized to cope with a maximum demand that rarely or never occurs.

When other control methods are used, such as dampers, vanes or valves, motors run at full speed and the flow of the output is mechanically restricted. For instance, the flow through a pipeline may be reduced by a valve, throttle or pressure reducer. This is wasteful, because the motor keeps running at its nominal speed regardless of demand. The pump delivers maximum output and the excess is reduced at the valve, where the surplus energy is wasted through friction.
A pump or fan running at half speed consumes only one-eighth of the power compared to one running at full speed, which means a small increase in speed requires a lot more power.

**VSDs deliver accurate control and less mechanical wear, reducing maintenance and extending the life expectancy of systems.**

The potential to save power

The amount of energy that can be saved depends on the type of load being driven:

- **Variable Torque Load**, is typical in applications such as centrifugal fans and pumps. It has the largest energy-saving potential - reducing the speed of the fan or pump by a small amount causes a significant reduction in the amount of power used because pumps and fans are governed by the Affinity Law of Power $\alpha (\text{Speed})^3$.

- **Constant Torque Load**, is typical in applications such as conveyors, crushers, air compressors and surface winders. The torque does not vary with speed, which means the amount of power absorbed will be directly proportional to speed - a 50% reduction in speed will result in a 50% reduction in power used.

- **Constant Power Load**, is typical in applications such as centre winders and machine tools. The power absorbed is constant whilst torque is inversely proportional to speed, which means a reduction in speed rarely achieves energy savings (Torque $\alpha 1/\text{Speed}$).

The largest energy savings can be achieved from variable torque loads whose outputs have been regulated in some way.

The advantages of VSDs go beyond improved energy efficiency - they:

- Enable precise control over applications such as conveyors or winders and can also help to control pressure, flow and temperature
- Allow for soft starting, which can reduce stress on motors and bearings and, therefore, extend equipment life
- Enable more frequent starting and help to reduce motor heating
- Allow dynamic braking to decelerate loads in a quick yet controlled manner
- Help improve the power factor
- Allow rapid adjustment of speed, torque and power to provide better control in high-speed applications
- Deliver meaningful intelligence on the status and performance of motors when interfaced with computers or wider process control systems, such as building management systems
- Avoid penalties for exceeding the supplied kVA
- Can run more than one motor at a time if the load on the motors is equal - in fact, up to six fans with the same load can be controlled by one VSD.
- When linked by remote control, can be used to switch off motors or lower the speed of fan or pump motors to decrease the air or water flow rate during Eskom’s peak hours of demand for electricity.

Some VSDs can regenerate power - there are options available where the rectifier stage is similar to the inverter stage, making it possible to return energy recovered during the electrical braking of the load to the electricity supply. A smart VSD with a built-in Programmable Logic Controller (PLC) can do sequence starting and sequence stopping and, therefore, replace a number of devices.
When a motor is started at full voltage without the use of a VSD it could draw up to 400% of its rated current whilst producing only 50% of its rated torque.

Putting VSDs to work

• Before installing one, make sure that the system to be controlled is efficient and correctly sized for its application. Only opt for a VSD if it is the correct electro-technical solution.

• VSDs must be correctly installed to operate optimally and achieve the intended energy savings - always select an expert installer who understands your process’ operating profile.

• Like all electrical equipment, VSDs are susceptible to damage from dust, humidity and inadequate cooling. Ventilation and/or air gaps must be provided (according to manufacturers’ specifications) to prevent overheating. VSDs should be located near the motor in suitably ventilated enclosures or remotely in a suitably protected area.

• Full energy saving gains will be achieved when harmonic filter protections and components are properly installed and tested.

• Since VSDs are dust sensitive, an appropriate dust filter needs to be installed when operating in dusty conditions – they also need to operate within specified temperature and humidity parameters.

• VSDs must be installed by qualified installers that can back up their product.

• Once installed, VSDs must be correctly programmed to deliver the intended energy savings - setting incorrect parameters results in poor control and energy wastage.

• Regular maintenance of VSDs - and associated motors - is essential to maintain energy savings. VSDs can become inefficient over time if they aren’t adequately maintained, especially in demanding environments with heavy loads.

• Preventive maintenance is always less expensive than correcting faults and having unanticipated breakdowns - opt for a maintenance contract with a reputable supplier to ensure that VSDs are kept in optimal condition.

Important to know

• Some older motor designs may not have enough electrical insulation in their windings to withstand the high voltages that can occur with VSDs - they must be checked to determine whether they are suitable for VSD controls.

• In some applications, mainly in motors 90kW and higher - or where high switching frequencies are used - there is a risk of stray electrical currents being induced in motors, which can damage bearings.

• VSDs can increase harmonics in the electricity supply, which disturb the sine curve of the Alternating Current and cause motors to run warmer than they are designed for, reducing their life expectancy. Harmonics can also decrease the life expectancy of computers and negatively influence the operation and accuracy of electronic measuring devices. The appropriate harmonic filters and chokes must, therefore, be installed along with the VSD to filter out the harmonics and protect your equipment.

• Motors operating under VSD control tend to run a little hotter than motors directly connected to the electricity supply; alternative methods of cooling may be required. The threshold for additional cooling will depend on the installation - in some
applications motors may be derated to ensure adequate cooling. The reason for that is that an electric motor is equipped with a fan to cool it down. If the speed is lowered to below the specifications of the manufacturer, overheating may occur and additional fans or ventilation might be required.

• If you have a power factor correction capacitor installed, remove it before installing a VSD.

Some equipment - the majority of the hermetic type compressors - is not designed to operate at reduced speeds and could get damaged. Check with suppliers to ensure your equipment is compatible with variable speed operation.

Safety considerations

• VSDs contain Electrostatic Discharge (ESD) sensitive parts and assemblies.
• Static control precautions are required when installing, testing, servicing or repairing VSDs.
• Component damage may result if ESD procedures are not followed - allow VSD capacitors to discharge for approximately five minutes before commencing with work or an inspection.
• The enclosure housing the VSD must be large enough to allow for the correct level of ventilation.
• Earthing is critical: Both the motor and the drive must be earthed according to installation guidelines.

Investing in correct VSDs for your system or process and regularly maintaining motor drives will save you downtime and money and ensure optimal energy efficiency.

Eskom’s Energy Advisors are on standby to assist you.

Eskom’s national Advisory Service offers information on manufacturers and suppliers of VSDs. The team can also advise businesses on:

• Reducing energy usage
• Doing walk-through energy assessments to identify energy usage patterns, energy needs, areas of energy wastage and energy saving opportunities
• Improving the energy efficiency of operations and electrical systems and processes
• Prioritising maintenance as an important contributor to reducing energy usage; and
• Finding SANAS approved energy savings Measurement & Verification Authorities.

Advisors also provide information on funding opportunities for energy efficiency projects.

Call 08600 37566, leave your name and number and an Eskom Energy Advisor will contact you, alternatively ask for a specific advisor to contact you.

Visit www.eskom.co.za/idm for more information.

Credits:

www.carbontrust.com
Fanie Steyn, technical paper - Energy savings on motor-driven systems (Johannesburg, South Africa, 2012)