Sensible flow saves

Variable Speed Drives (VSDs) – saving energy in the industrial sector

Eskom

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Variable Speed Drives

1. Sustainable use of electricity is a necessity

In common with most other countries in both the developed and the developing world, South Africa needs more generation capacity. The extent to which Eskom is able to supply the country's demand for electric power has a direct impact on economic growth.

All sectors of the economy can reap major benefits from implementing energy efficiency policies. By optimising processes and plant efficiency, companies reduce input costs and increase their return on investment. As an added benefit, reduced energy consumption means reduced environmental impact, an important part of the "triple bottom line."

This information brochure aims to assist industrial and commercial users of electricity to improve the energy efficiency of motor drives. It explains the benefits of optimising the energy efficiency of drives, types of drive control and common problems affecting drive efficiency before describing a number of measures to improve operating efficiency and thereby reduce electricity usage and costs. It concludes with a summary checklist and details of free energy efficiency advisory services available from Eskom. The following graphs show which applications lend themselves more towards variable speed drives. In Figure 1, much of the required flow is well below 100% capacity well suited, whereas, in Figure 2 the flow required is above 80% capacity - not suited.

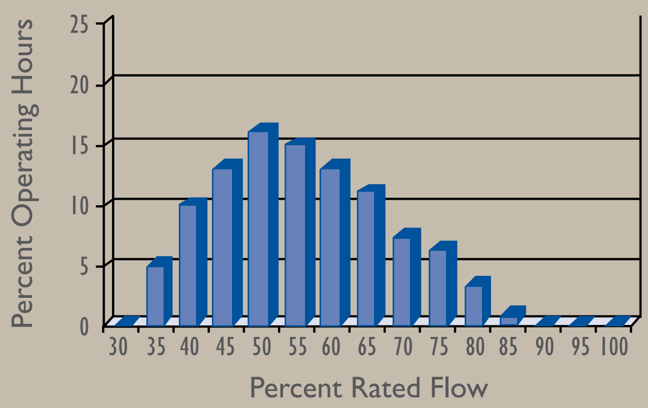

Figure 1: Example of an Excellent Variable Speed Drive Candidate

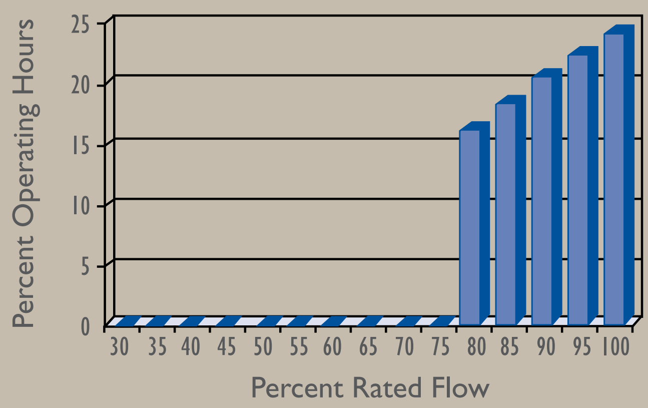

Figure 2: Example of a Poor Variable Speed Drive Candidate

2. Background on adjustable drivers

When Henry Ford devised a mechanical assembly line for his motor cars in the early 20th century, it soon became apparent that controlling the speed of the process was of fundamental importance. If the line was too slow, production targets would not be met; if it moved too fast, mistakes happened and quality suffered.

Early methods of controlling the speed of various processes were inefficient and wasteful of energy. Fans, pumps and conveyors were equipped with sufficient power to meet maximum demand and then "throttled back" to achieve the desired output by means of baffles, shields, valves and brakes.

As processes became increasingly automated, research focused on finding more efficient methods of speed control. Depending on the application the following methods were developed:

- Mechanical
- Hydraulic
- Electronic.

2.1 Mechanical adjustable drives

There are various types of mechanical drives:

- Variable pitch drives
- Traction drives
- Variable speed gearboxes
- Fluid couplings
- Magnetic couplings
- Steel shot couplings.

2.2 Hydraulic speed control

Types of hydraulic drives include:

- Hydrostatic drives
- Hydrodynamic drives
- Hydro-viscous drives.

Both mechanical and hydraulic drives have been used for many years. Although in certain applications they are irreplaceable, they do not have the efficiency, flexibility or the responsiveness of new-generation electronic devices. They also do not have the same control when it comes to speed control, the ability to run at lower speeds, also the ability to be fine-tuned for maximum efficiency of the motor.

2.3 Electrical (electronic) speed control

There are various types of electrical (electronic) drives:

- Direct current drives
- Eddy current drives
- Soft starters
- Variable frequency drives.

Other methods include:

2.4 Direct current (DC) drives

This is the older type of electronic speed control used in industry for varying the speeds of DC motors. The speed of a DC motor is directly proportional to the armature voltage and inversely proportional to the field current, therefore the armature voltage or the field current could be used to control the speed of the motor.

2.5 Eddy current drives

These consist of a fixed speed motor and an eddy current clutch. The clutch contains a fixed speed rotor and an adjustable speed rotor, which are separated by a small air gap. The controller provides closed loop speed regulation by varying the clutch current, only allowing the clutch to transmit enough torque for the desired speed. When the motor starts to run, a magnetic field is induced into the eddy current clutch. This current can be controlled through an electronic controller. By increasing the magnetic field the speed of the output shaft will be faster.

3. Energy efficiency benefits of variable speed drives (VSDs)

VSDs, also known as adjustable frequency drives (AFDs) or variable frequency drives (VFDs), are typically used for process control and, lately, more specifically for energy conservation.

VSDs are becoming the most commonly used method for speed control in industry. They control the speed of the induction alternating current (AC) motor to which they are connected, and are the most energy efficient means of controlling the speed of a motor.

VSDs have the ability to vary the voltage (V) and frequency (Hz) simultaneously. Thus, the speed of induction motors can be controlled from 0Hz to 400Hz.

3.1 Electric motor start-up options

The most common way of starting induction and asynchronous motors is by using "direct on line" (DOL) starters or "star-delta" starters. This technique is suitable for certain types of machines but there are some disadvantages for these types of starters:

- The inrush current on start-up is extremely high; this could interfere with other devices that have been connected to the same voltage supply
- Mechanical shocks during start-up increase maintenance costs and shorten the life of the machine, pumps and pipelines
- Acceleration and deceleration cannot be controlled
- Speed cannot be controlled.

3.2 Start-up currents

These are the start up currents using the various methods of starting:

- Direct on line starter (DOL) 6 - 9 times the full load current
- Star-Delta starter (ASD) 4 - 6 times the full load current
- Soft Starter (SS) 2 - 4 times the full load current
- Variable speed drive (VSD) 1,5 times the full load current.

When a motor is started without the use of a VSD at full voltage, it could draw up to 300% of its rated current while producing only 50% of its rated torque.

4. Applications and examples of the benefits of VSD control

With advances in the electronics industry the technology has improved significantly, extending the VSD's field of use.

- Besides using VSDs on fans and pumps there are various other areas in industry where one can consider retrofitting drives
- When using a VSD on a mixer, the speed can be increased to speed up mixing then slowed down once the mixing has been done. At this stage the mixer can be kept at constant slow speed to keep the liquid mixed until it is used
- Other areas where a VSD could be used are conveyor systems in plants
    - If a production line can be slowed down from 100% to 80% this will also be a saving
    - If you go one step further with a small PLC and sensors, the conveyors could be stopped (or slowed down) when there is no product on them
    - As the product starts to move, reaching various conveyors, they can be started up (or the speed could be increased slowly)
    - Start-up is gentle and does not cause any damage to the product on the conveyor belts
    - When a VSD senses that it is in "idle mode" for a time it can go into a "sleep mode" until it needs to start up again
- When water pumps in blocks of flats or offices need to maintain a certain system pressure but no water is used for a time then the VSD senses this and goes into sleep mode. When a tap is opened the pressure will drop, a pressure transducer will detect this and will ramp the VSD up slowly to increase the pressure required in the pipes. Slowly increasing speed of the motor eliminates all water hammer in the pipes, therefore decreasing maintenance on the piping of the building.

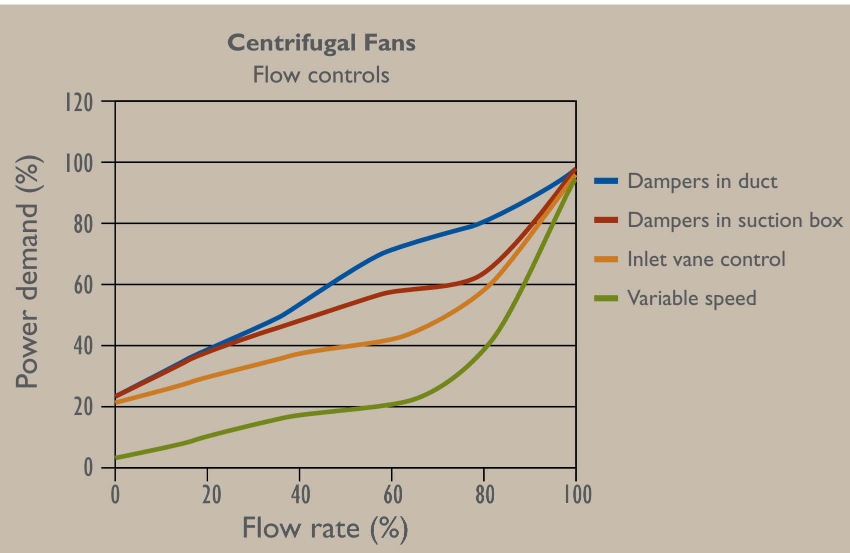

Figure 3: Power Consumption (Audit Procedures Manual – SADCC)

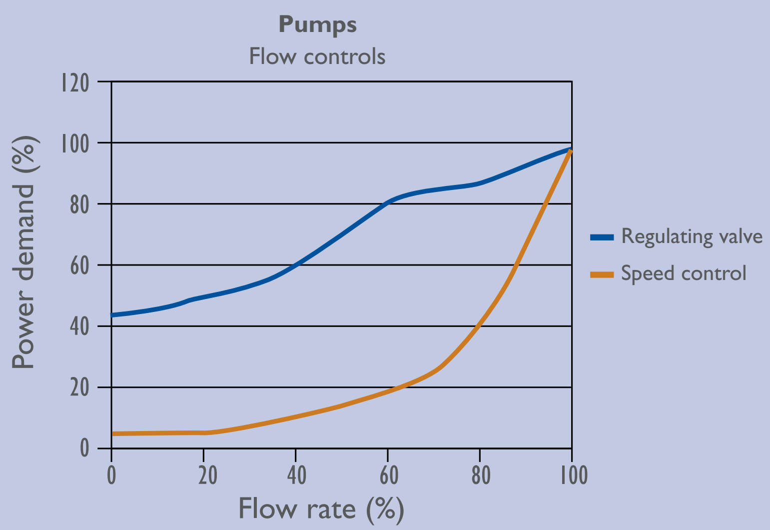

Figure 4: Power Consumption (Audit Procedures Manual – SADCC)

4.1 Savings

Operating motors more efficiently, through the optimal matching of motor output to process requirements, delivers significant savings:

- Reduced power consumption
- Reduced maintenance cost due to smoother starting
- Increased process efficiency and safety
- Reduced pressure on scarce skills
- Reduced capital investment.

4.2 Turning objections into advantages

The usual objection to installing a VSD is the initial cost. But this narrow view is illusory because of the following benefits:

- A VSD saves energy; therefore, savings on energy costs actually "pay for it"
- Electricity tariff increases have reduced payback time period
- Penalties for exceeding the supplied kVA are avoided
- A VSD can run more than one motor at a time so the number of drives can be reduced
- With a small PLC it can do sequence starting and sequence stopping, replacing a number of devices.

5. Guidelines for the use of variable speed drives

5.1 Operating principle

The voltage at the input power side is processed by a rectifier circuit and is changed from an AC voltage to a DC voltage. Next an inverter circuit (also known as the pulse width modulation circuit) converts the DC voltage to a chopped sinusoidal wave, producing Variable Frequency power to the input of the drive motor(s).

By controlling the pulse width of the voltage and frequency the speed of the motor will be increased or decreased accordingly. The voltage and frequency are directly proportional to each other, so the lower the frequency the lower the voltage and the slower the speed.

5.2 Operation

When a VSD starts a motor, it initially applies a low frequency and voltage to the motor, typically 2Hz or less. This avoids the high inrush current that occurs when a motor is started using a direct-on-line or star-delta starter method.

The applied frequency and voltage is increased at a controlled rate to increase the speed of the motor (load) without excessive current being drawn. This method of starting allows the motor to develop 150% of its rated torque at only 50% of its rated current.

When a motor is started without the use of a VSD at full voltage it could draw up to 300% of its rated current while producing only 50% of its rated torque. The VSD can be programmed to hold the torque at a steady 150% from start-up to full speed while only drawing 50% of its rated current.

5.3 Cautions

- Do not exceed the rated motor speed because this could cause the motor torque to drop
- If the motor or the bearings are not designed for such speeds this could result in motor failure
- Do not put a power factor correction capacitor after the VSD
- The VSD corrects the power factor of the motor automatically
- If a capacitor is already fitted it must be removed before starting the drive
- Power factor correction at the main supply (before the VSD) is acceptable and need not be removed
- Match the electrical characteristics of the VSD to the motor
- VSDs produce high shaft currents that can lead to bearing and motor failure
- Some old motors cannot handle the drive's high rate of switching and the insulation could break down
- There could be electromagnetic disturbances that could also affect the motor
- Long cable runs can cause transmission line effects under low load conditions i.e. raised voltages at the motor terminals
- The distances to the drive and then the distance to the motors could lead to lower voltages at point of supply or at the motor.

5.4 Solutions

- Match the proposed VSD to the motor's nameplate information
- Use the motor's full load current not the calculated current to select the correct size drive
- Use new, energy efficient motors where possible
- Do not exceed the rated frequency, voltage and current of the motor
- Fit insulated bearings to both ends of the motor
- Motors > 100kW: common mode filters can be used with the changing of the bearings
- Earthing is critical: motor and drive must both be earthed to the main earth
- Use high frequency bonding connections between motor frame and the rest to equalise potential
- Use braided copper straps 50 -100mm wide to reduce the impedance path around the wires
- Apply the supplier's technical information on cable distances, filters, chokes
- Persuade your supplier to assess your requirements, application and distances.

6. Types of optional equipment

- Input line reactor - when line voltage imbalances are >2%

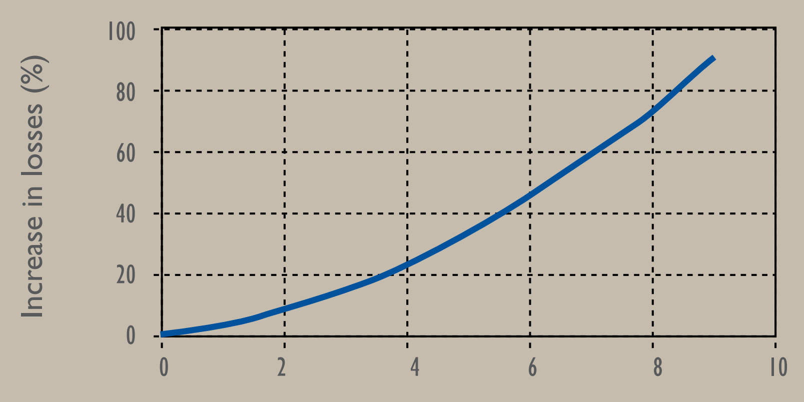

Figure 5:

- Main circuit breaker or switched fuse isolator - depending on recommendations
- Line reactor - External Electromagnetic Compatibility (EMC) filters for long motor cables and/or domestic installations
- Output device or cable termination - if motor cable lengths exceed stated values
- This information can be obtained from the suppliers on request
- Information for the various types of drives is also available online.

7. Safety

- VSDs contain Electrostatic Discharge (ESD) sensitive parts and assemblies.
- Static control precautions are required when installing, testing, servicing or repairing
- Component damage may result if ESD procedures are not followed (allow the capacitors to discharge for approximately one minute before commencing with work or an inspection)
- The enclosure that is going to house the VSD must be large enough to allow the correct ventilation for the drive. Ventilation and/or air gaps must be provided (according to manufacturers specification) to prevent overheating
- Earthing must be done exactly according to installation guide stipulations.

8. Starting

- Drives have capacitors that hold a charge: test for voltage before starting work on the drive
- After switch-off let the capacitors discharge completely (approximately one minute)
- To test the voltage go to points +DC terminal of the power terminal block and the - DC test point. The voltage must be zero
- Before start-up, check the input supply voltage; output wiring; input wiring; control wiring
- Most drives have a quick or smart start to help you set up the drive.

9. Selection

It is important always to select the correct drive for the application. Many drive manufacturers have drives that are specifically designed for pumps and fans. Make sure that a drive that is designed for pumps is used for pumps and not for a gearbox. Select a service provider in your area to ensure good back up and after sales service.

When fitting new motors ensure that your specialist supplier conducts a proper needs analysis, replaces oversized motors and ensures new units are sized at optimum efficiency, with VSD controls.

10. Set-up

A drive must be installed and set up correctly:

- The overload setting must not be too high (this can negate overload protection)
- The overload setting must not be too low (this can cause nuisance tripping)
- The maximum allowable frequency must be set to avoid damage from higher speeds or frequencies
- Train operating and maintenance staff in correct use of the VSD drives
- Establish and follow a regular maintenance programme.

11. Energy Efficiency Checklist

Good selection and regular maintenance of motor drives and their controls make perfect energy sense, saving your business downtime and money. Shown opposite is a summary of relatively simple actions that you can take with the drives that support your business:

Checklist for the most important energy efficient options:

	Check	✔
1	Identify all motor applications that do not need to run continuously at full power.	
2	How would changing the speed of the driving motor cause a change in the process or its rate?	
3	Will product quality be improved or impaired?	
4	What effects will the improvement or impairment have?	
5	In what way can the machine operate at other than its current speed?	
6	In what way can any speed-changing equipment be installed to provide suitable electrical signals?	
7	Describe the physical space for installing a new or additional electrical motor controller.	
8	If the existing constant speed motor is a totally enclosed fan cooled induction motor, how would additional ventilation be provided if needed, when operating at lower speeds using a VSD?	
9	What drawings or other means are available to validate the construction or installation details of the motor and machinery involved?	
10	Consider cost/benefits of VSD drive control for these motors. • How will a change in the speed of the driving motor result in a lower energy requirement? • How many hours per week does the equipment operate? • What are your electrical energy costs in terms of your utility bill (consumed kWh, demand charges, etc.) or in terms of product costs? • What are the costs of maintaining existing mechanical and/or electrical speed-changing equipment (transmissions, dc and wound-rotor motor, or reduced voltage starting etc/)? • Are they obsolete and in need of replacement? • How will the use of a VSD improve quality (through better speed control, elimination of waste, product reversion, etc.) and/or ultimately result in lower product costs? • What costs associated with drive inefficiencies (friction heat, cooling water, etc.) can be reduced by using an energy efficient VSD system?	

12. Support and advice

There are a large variety of well-known Variable Speed Drive brands and models available in South Africa. Advice on the many techniques and technologies that are available for the purpose of saving energy can be obtained from suppliers, consultants or Eskom's energy advisory service. Interested persons can call the Eskom Contact Centre on **08600 Eskom (08600 37566)** and log a query for an energy advisor in their area to contact them or visit the website on **www.eskom.co.za/dsm**

13. References

1. Eskom commissioned research 2008
2. Eskom Demand Side Management
3. Audit Procedures Manual - SADCC

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