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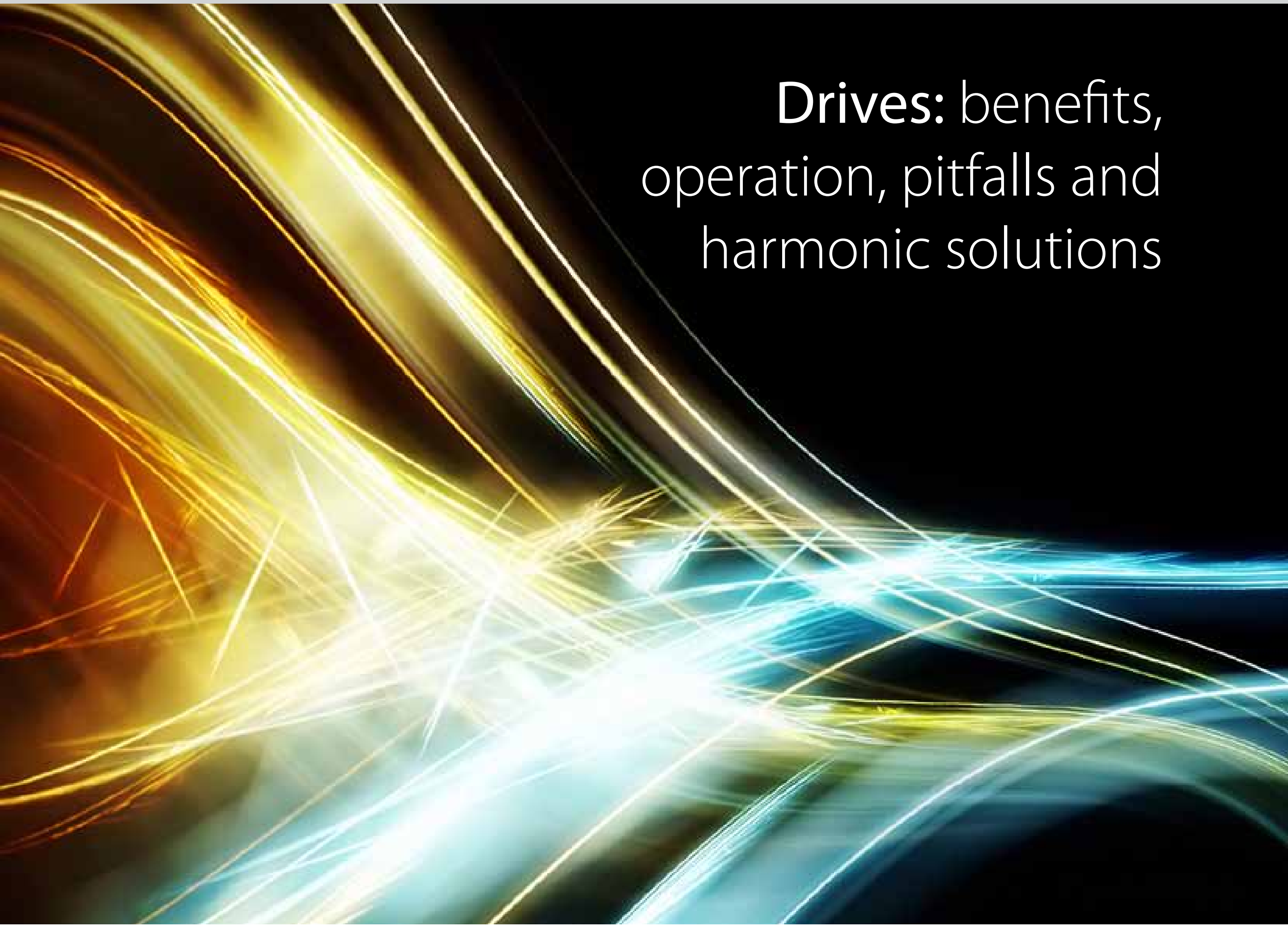
Technical News

INDUSTRIAL ELECTRICAL AND AUTOMATION PRODUCTS, SYSTEMS AND SOLUTIONS



Drives: benefits, operation, pitfalls and harmonic solutions

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The electric induction motor has been used in industries since the late 1800's. Motor speed was determined by the number of poles or multiple fixed speed windings in the stator. Early speed regulation was possible using DC motors, but these were inherently a high maintenance item and very expensive. With the onset of progress in power electronics, it was becoming possible to replace DC motor speed control with AC induction motors using electronic starting methods.

Earlier electronic AC Variable Speed Drives (VSDs) were made possible by the 1957 introduction of the silicon controlled rectifier (SCR), however as they were connected to a DC bus they did not turn off automatically and needed forced commutation to turn off the SCR. In the 1980's the Insulated-Gate Bipolar Transistor (IGBT) became the prevalent device for the inverter section of the VSD (replacing SCRs), and has remained so for low voltage drives to date.

Latest developments include advanced algorithms which allow increased functionality. For example,

torque control, which enables the drive to run using a torque reference, and improved sensorless vector control offering greater torque at very low speeds without the use of an encoder.

WHY? SOME OF THE BENEFITS OF USING VARIABLE SPEED DRIVES

"Significant energy savings are possible by running equipment like pumps and fans only at the speed needed to meet the demand"

Pump energy saving tool

- *Optimise plant productivity*
- *Energy savings*
- *Reduction of peak demand*
- *High level of Automation*

- It's possible to optimise plant productivity and quality by accurate control of motor speeds to fine tune a complete process. We can also accommodate for a changing process or machine requirement. For example, we can alter a pump speed to accommodate changes in water supply demand, alter the speed of manufacturing, or cater for changing ventilation requirements in a building.
- Significant energy savings are possible by running equipment like pumps and fans only at the speed needed to meet the demand. A common retrofit application removes throttling valves and uses a variable speed drive on a pump.
- Significantly reduces starting current to minimise peak demand and reduce associated tariffs. Variable speed drives offer the best technology to minimise current draw on start up. Not only does this avoid the fixed cost charges associated with a huge peak demand, but it is also possible to keep starting the motor many times an hour.
- High-level automation is possible, which means we can monitor the drive and change parameters on the fly. For example, if four different products are made on one process line it is possible to quickly download different parameter sets for all drives and switch to the new product. This also offers a high degree of remote monitoring.
- VSDs have inherent soft starting/stopping capabilities thus reducing mechanical shock and eliminating water hammer in pumping applications.
- Drives also offer a power factor close to unity, so no additional power factor equipment has to be used for motor loads which are supplied by variable speed drives.

HOW DOES A VARIABLE SPEED DRIVE WORK ANYWAY?

"A drive changes the speed of the motor by changing the frequency to the motor"

This brief discusses in a simple way what a drive actually does to change the speed of a motor, and some of the associated benefits. Most technical issues that arise from the use of a Drive stem from the essential elements of how a drive operates, and a basic understanding of the fundamentals will help understand these more easily.

An adjustable speed drive controls the speed and direction of an AC or DC motor. Advanced drives can also operate in a torque control mode. We will consider only an AC motor and low voltage drives (up to 690 V). The speed of a motor is dependent on both the number of poles and the applied frequency.

n = (120*f* / *p)* - slip

Where **N** = RPM **F** = frequency **P** = number of poles

A drive changes the speed of the motor by changing the frequency to the motor. As an aside, the impedance of the motor is determined by the inductive reactance in the windings, and it changes as the frequency changes. In order to keep the current reasonable and maintain torque we lower the applied voltage to the motor as the frequency is reduced, and this is referred to as 'volts-hertz' control.

For example, consider a 4 pole induction motor, where the nominal speed rating is:

1490 rpm** at **50 Hz

Applying the equation we will achieve:

1192 rpm** at **40 Hz, or

894 rpm** at **30 Hz, etc.

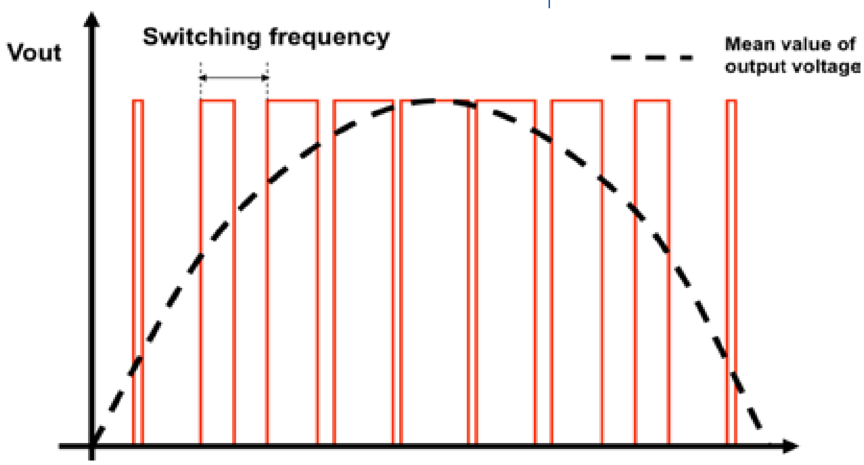


***Fig 1.** Pulse Width Modulation (PWM)*

To control the voltage and frequency to the motor drives, employ pulse width modulation (PWM) methodology. DC voltage is applied to the motor by controlled pulses at high frequency, which results in voltage that approximates a sine wave of the chosen frequency (***Fig 1.***). IGBT's or Isolated Gate Bipolar Transistors are the current technology used and can switch the voltage very fast. The switching frequency is typically in the range 1.6 kHz to 16 kHz.

In order to obtain DC for switching, a rectifier section is at the input of a drive, and this creates DC voltage on the DC bus. The inverter section at the output side provides the PWM waveform (***Fig.2***).

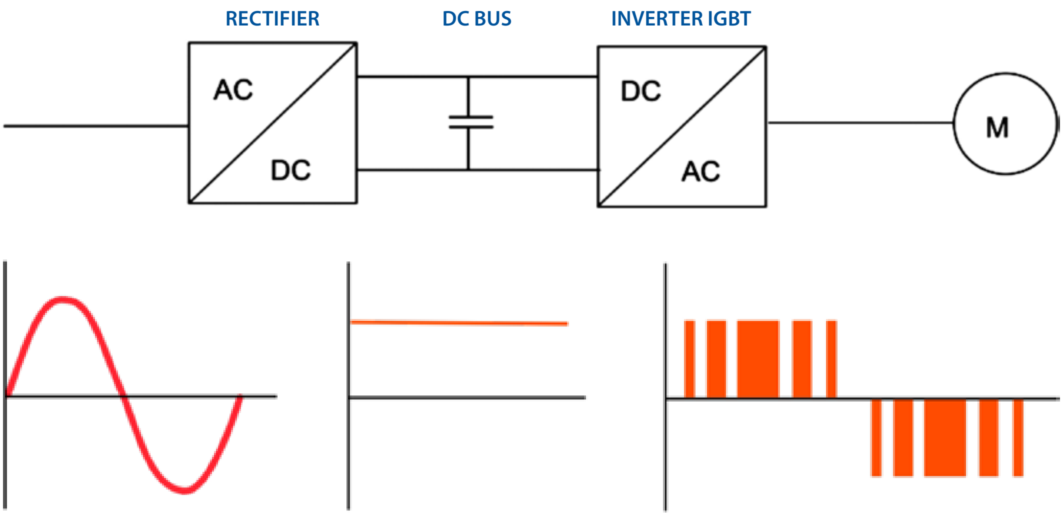


***Fig 2.** Typical LV drive topology and resultant waveform*

Affect on motor performance

Using a VSD affects the torque-speed curve of the motor, and the result is that we can maintain full torque across the normal speed range up to 50 Hz (***Fig 3.***).

With a high performance drive we have the ability to provide a high starting torque at low speed approaching the 'pull-out' or 'break-away' torque of the motor, providing the drive is selected with suitable overload capacity. Under normal load conditions, full motor torque can be provided up to 50 Hz, and then torque capacity reduces as shown right (***Fig 3.***). Running the motor above 50 Hz limits the torque output available from the motor as we move into a region of constant power, and as the speed increases the torque available decreases.

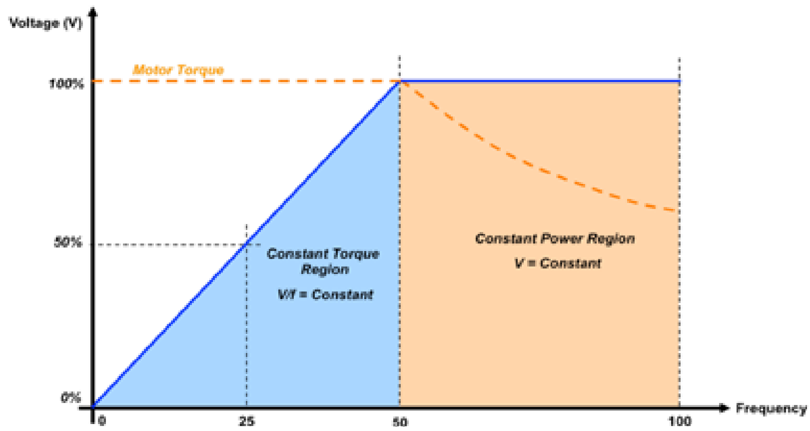


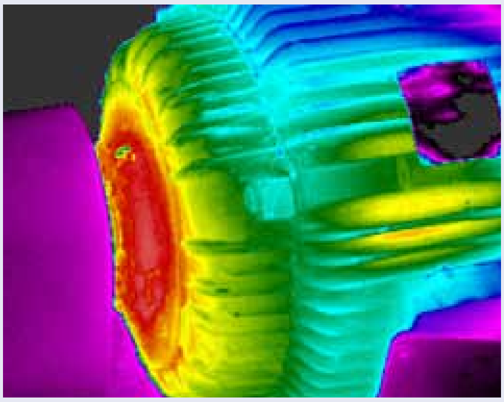
Fig 3. *Motor torque curve with VSD*

TECHNICAL CONSIDERATIONS FOR THE MOTOR

Using a VSD has a number of technical implications on the motor that need to be considered.

MOTOR COOLING

Use of the drive to run the motor at low speeds affects the cooling capacity of the motor fan, and with high torque loads this can lead to the motor overheating. Motor manufacturers usually provide data indicating when an externally powered fan is needed, in which case they fit a 'forced cooling kit'. As a rule of thumb, anything less than half speed demands external cooling and is of particular concern with a constant torque load.



BEARING CURRENTS

The high switching frequency can lead to 'capacitive bearing currents'. These currents flow through the bearings which can cause brinelling of the bearing surfaces. This is of particular concern above 132 kW, and motor manufacturers usually stipulate when their motor needs special precautions. Often the combination of an insulated non-drive end bearing is used, plus an earth brush kit. Alternatively a sine wave output filter can be applied to minimise bearing damage.

Fig 4. *Bearing race damage*

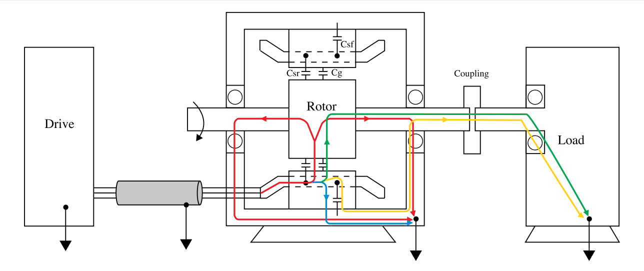


Fig 5. *Current paths of capacitive current*

NOISE

Motor noise output can be regulated by altering switching frequency. Often people raise the switching frequency of the drive to make the noise less noticeable to the human ear. The quality of the electric motor can also affect how loud this is. There are implications of an increased switching frequency and this can lead to increased losses and de-rating of the drive, as well as contributing to higher earth leakage currents. On the flip side, a lower switching frequency may mean a lower drive temperature, higher motor temperature and less leakage current. A sinus filter can be implemented to obtain quieter operation without the drawbacks of raising the switching frequency.

VOLTAGE SPIKES

High voltage spikes up to 1200 V are possible at the motor terminals, so it is important that the motor insulation is appropriately rated. Please note that the insulation voltage rating is distinct from the temperature class of the insulation. We are not referring here to the 'Insulation Class' of the motor which refers to temperature rise of the motor. High voltage spikes can occur due to reflected waves, and in this case we consider the cable length, impedance mismatch of motor and cable, and switching frequency. On a case by case basis we use output filtering to prevent spikes beyond what the motor can handle and mitigate reflected waves with the use of an output reactor, reflected wave filter or a sinus filter.

Fig 6. *Schaffner sine wave filter*

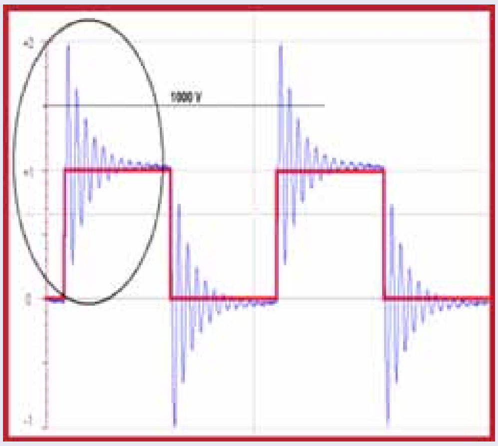


Fig 7. *Voltage spikes in motor cable*

HARMONICS AND SOLUTIONS

Variable speed drives create disturbance on the supply, and this has become a topic of discussion in recent times as people become more aware of the Standards and hidden effects of harmonic disturbance.

The presence of harmonics can result in reducing the life of other equipment on the supply, hotter cables and transformers resulting in shortened longevity, random tripping of protection devices, increased losses in DOL motors, and overload of power factor correction equipment.

Five popular solutions used to minimise harmonic disturbance.

MULTI-PULSE SOLUTIONS

Multi-pulse solutions, often with large kW drives, can be used to reduce harmonics without adding an additional filtering device. A 12-pulse solution uses two rectifier modules for the VSD and runs duplicated supply cabling to the drive from a transformer with two secondary windings. 18 and 24-pulse solutions are also on the market. Using this, the 5th, 7th, 17th, and 19th harmonics are cancelled out at the transformer, and typically reduce current distortion down to approximately 10 %.

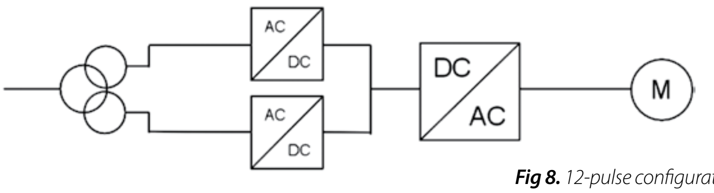


Fig 8. *12-pulse configuration*

REACTORS

The most common and significant starting point is often an AC or DC choke, and many premium drives have one of these integral to the unit. Without these, harmonic current distortion can be up to 100 % and the inclusion of this base level component will bring the current distortion down to approximately 35 %.

ACTIVE FRONT END

Active front end solutions are a second drive-based harmonic solution, and in this arrangement current harmonic distortion down to a level of approximately 4 % is achievable. As the name suggests, rather than use diode rectification we switch the incoming power to the drive using transistors and this offers a sinusoidal input current. As well as providing a low harmonic solution, a variation on this offers electrical braking with the excess energy being fed back to the supply, known as a Regenerative Solution. A higher purchase price is offset by reduced energy consumption for loads requiring frequent braking. Harmonics are also significantly reduced.

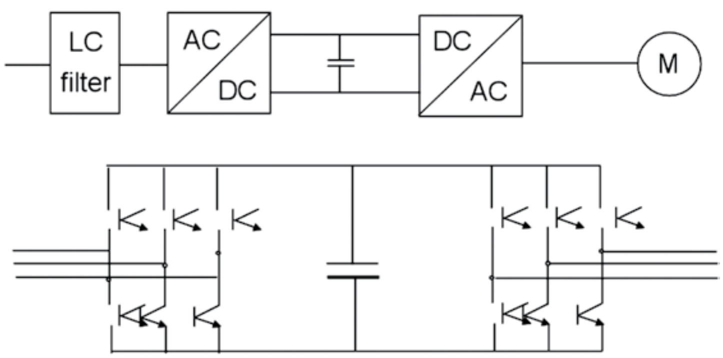


Fig 9. *Active front-end topology*

ACTIVE FILTERS

Active filters are a high end device for controlled and selective elimination of harmonics, and are great when there are a number of drives connected or where the load varies. They allow all standard 'off the shelf' drives to be used and provide some flexibility for the odd drive being added or changed. The active filter also sits in parallel, so you are not relying on the device to be operational in order for drives to have power. One active filter can compensate for a number of drives, so it is a smart solution to achieve harmonic compliance, at a level of approximately 4 % current distortion.

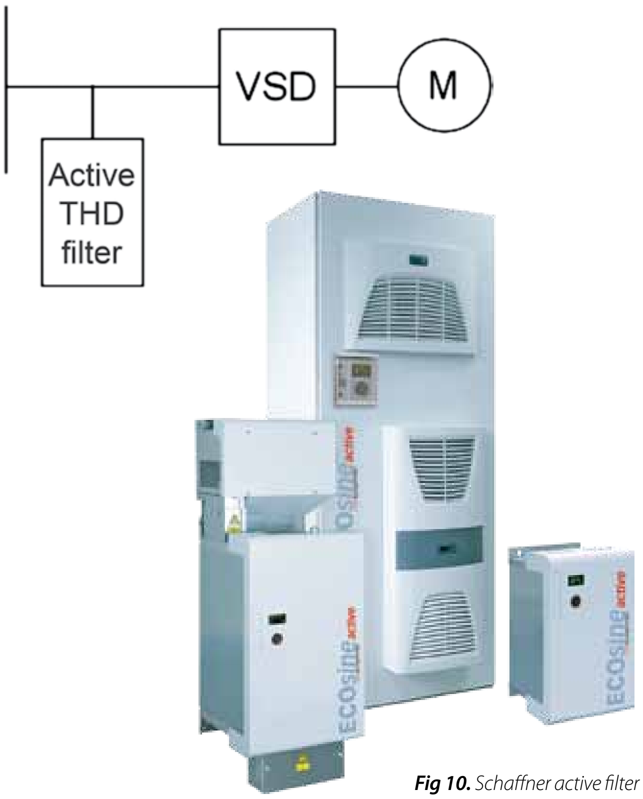


Fig 10. *Schaffner active filter*

PASSIVE FILTERS

Passive filters are usually applied for smaller drive installations. They sit in line with the supply to the drive and are often available as a 5, 8, or 10 % filter. Capacitors may be switched out when at low load in order to avoid a leading power factor situation. A passive filter is easy to install and helps reduce the harmonics right at the drive.

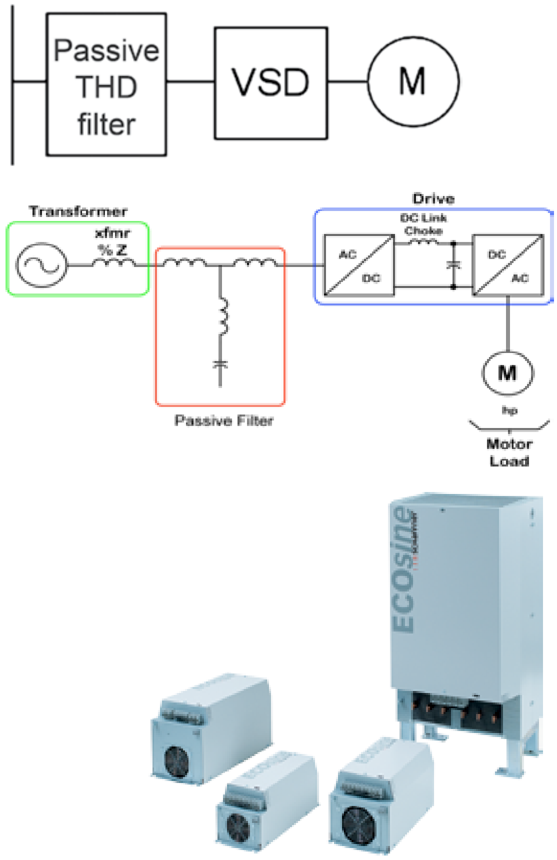


Fig 11. *Schaffner passive filter*

CONCLUSION

AC drives have been developed to the point where they can typically match the level of performance of a constant torque DC drive system, however, doing so more economically and with less maintenance. Some advantages of using variable speed drives include optimising productivity, energy savings, reduced starting current and peak demand charges, and a high level of automation.

NHP are well placed to discuss your application in detail and offer the best technical solution to your VSD system design.

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