Abstract

This application note describes the benefits of using VLT 5000 for extruders in the plastics and man-made fibre processing industries.

Introduction

An extruder is the name of a machine which pushes different kinds of materials through a die. Many different materials can be extruded, such as clays, foods, metals, chemicals and plastics. Depending on the material and application - extruders come in numerous types and sizes.

The most common type of extruder is the screw extruder which is used in the plastics and man-made fibre processing industries:

The material is usually fed into the machine as a solid granulate. After plasticating or melting the material the screw pushes the material to a die or spinning head which determines the shape and size of the final product. Typical products: Blown plastic films, plastic pipes, plastic profiles and man-made textile fibres.

Fig. 1 shows a typical screw extruder for plastics processing. The raw materials enter the extruder in the feed section and the rotating screw moves the material forward to the compression section. In this zone the pressure builds up and the friction between the granulated particles plasticates the material. In the metering section the liquid material is pushed to the die.

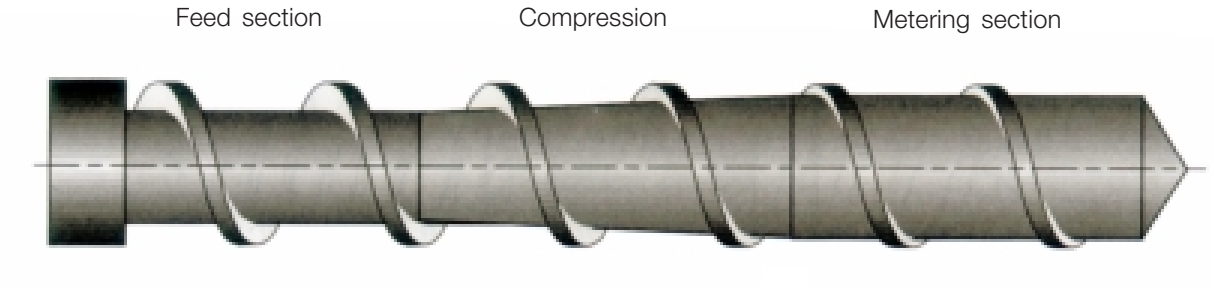


Fig. 1

■ Directly driven extruder

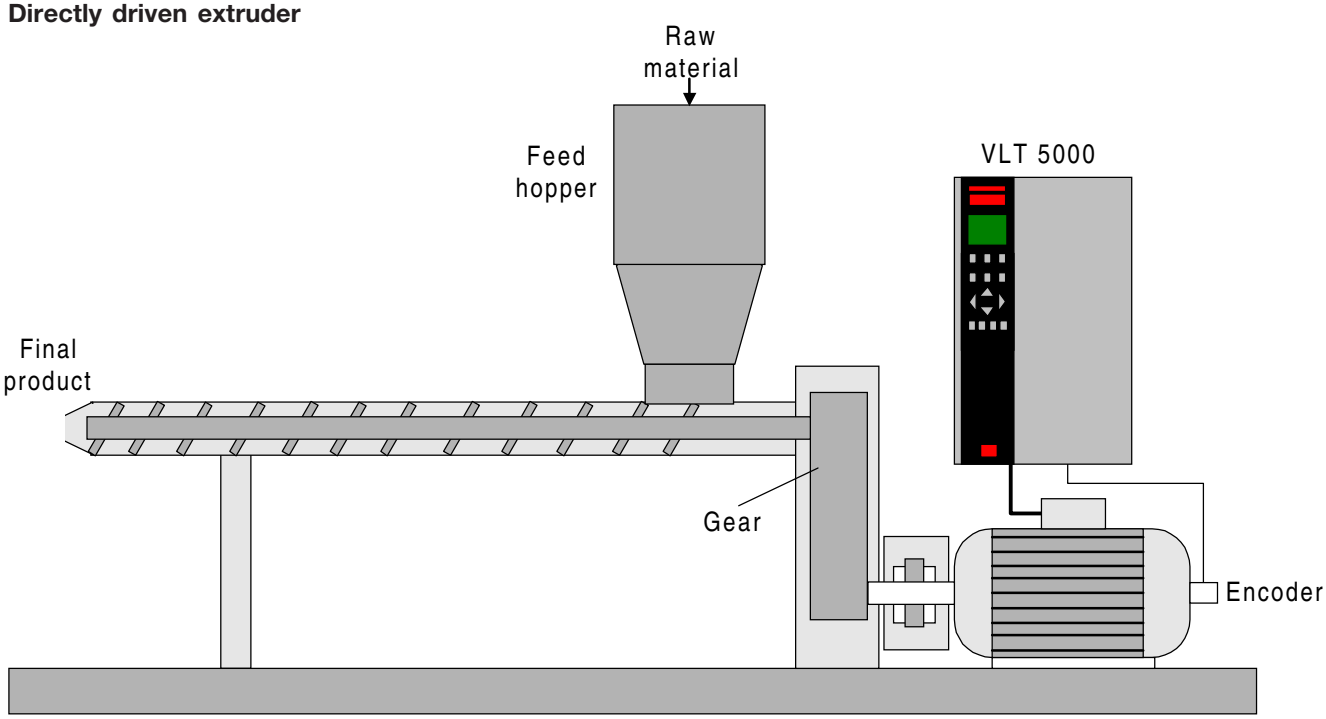


Fig. 2

Fig. 2 shows an example of an extruder with a direct drive.

A screw extruder can have one screw (single screw extruder) or several screws. The single screw extruder is the most common extruder in the plastics processing industry. The typical speed of a single screw extruder is 100 rpm, where two screw extruders run at either high or low speed, depending on the application.
A typical high speed two screw application is used where two products are mixed. Here the speed is about 200-500 rpm. Low speed extruders with two screws run at 10-40 rpm and are often used in profile extrusion applications.

When there is a direct coupling between the motor and the gearbox, the extruder is directly driven, see fig. 2. The advantages of direct driven extruders are:

- No belt slippage
- Better energy efficiency
- Fewer mechanical parts

The disadvantage of a directly driven extruder is that it is (more) difficult to change the reduction ratio for different products.

■ Indirectly driven extruder

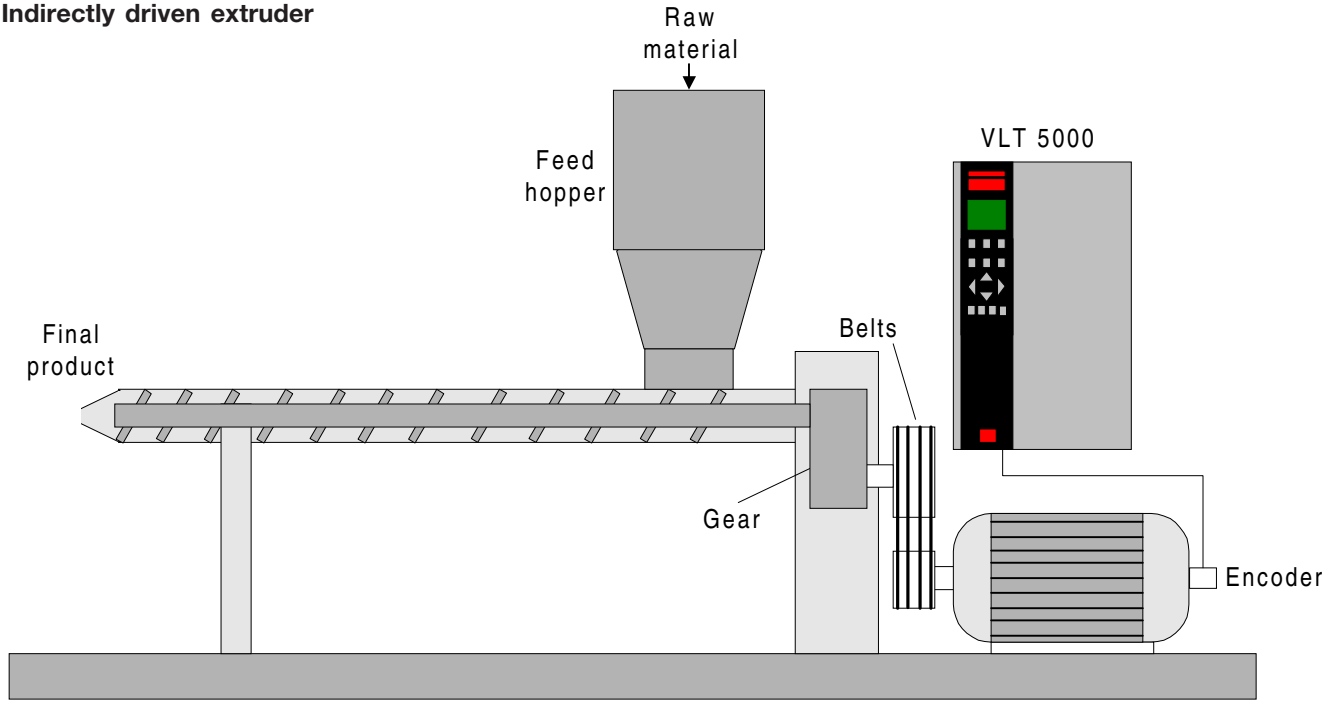


Fig. 3

When there is a belt between the motor and the gearbox, the extruder is indirectly driven, see fig. 3

The advantages of indirectly driven extruders are:

- Easy to change the reduction ratio
- More freedom to place the motor
- Less torque ripple

The disadvantages of indirectly driven extruders are:

- Belt slippage
- Energy loss in the belts
- More mechanical parts that can wear out and fail

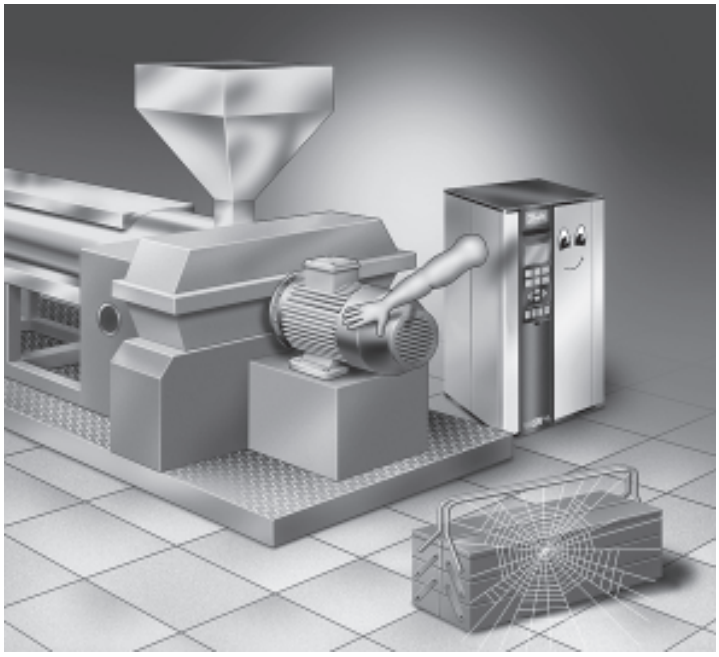
■ The tradition:

In a traditional extruder system the screw is driven by an electric DC motor and it is either driven directly by a gearbox or indirectly through belts and sheaves at the gearbox.

Traditional DC motors have some disadvantages as they need replacement of brushes approx. every 6 months. In dusty or aggressive environments the DC motor must be cleaned regularly and in some cases clean cooling air for the DC motor must be supplied from the outside of the building.

Primary symptoms of DC motor problems are excessive noise, brush sparking, discoloured armature, high motor temperature, inadequate exhaust air flow and motor vibration. Therefore, the extruders with DC motors are more expensive to maintain and the initial costs of DC motors are higher.

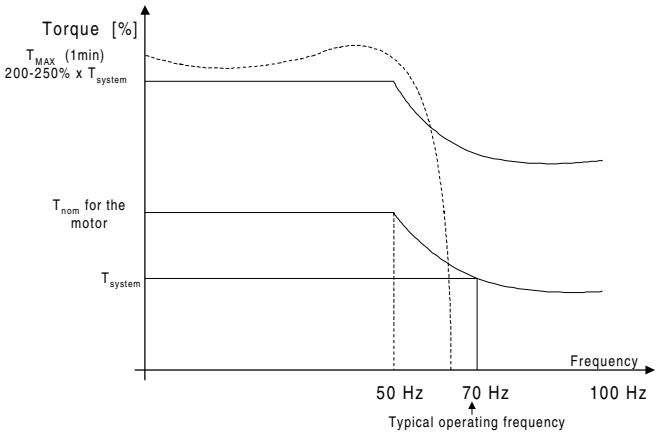
■ The new standard:



● Improved technology:
A few years ago the power electronics in frequency converters were not able to give AC motors the same shaft performance as a DC motor.
Furthermore, AC drives were more expensive than DC drives.
But with the recent progress in power electronics and microprocessor technology, the AC system has become a better and a more cost efficient solution compared to a DC system for many applications.

● Improved performance:
By replacing the DC-motor with an AC motor and controlling the AC-motor with VLT 5000 you will have the same speed control and performance as a DC motor. The extruders are often fitted with encoder feedback and as the speed deviation of VLT 5000 in closed loop mode is less than 0.1% it is far better than most DC drives. When operating in open loop mode (without encoder feedback) the speed deviation is less than 0.5 %.

The required brake-away torque for the extruder screw may go as high as 200-250% of nominal torque. Using AC systems this is solved by selecting an oversize drive or operating the motor up in the field weakening range. The full nominal torque is usually not needed at full speed.

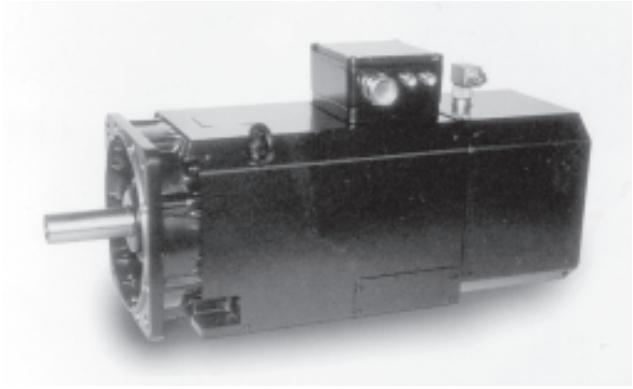


■ The new standard:

● Improved energy efficiency:
The energy efficiency of an AC system with VLT 5000 is typically 5% higher than in a similar DC system. The efficiency in a high quality AC motor is better than in a DC motor and the VVC^{plus} control system of the VLT 5000 ensures optimum shaft performance without excessive heating.
Extruders use a large proportion of the electricity in a plant. The VLT 5000 creates much less harmonic current distortion (better power factor) than a DC drive, thus eliminating the need for oversizing the transformer and cables.
Extruders are often fitted with square frame AC motors with superior torque characteristics and dimensions similar to DC motors.
AC systems are price competitive up to approx. 50-100 kW when comparing cost price only. However, when considering the total cost of ownership, AC systems are competitive up to approx. 200 kW.

● Improved environment:
As the extruder plants often are situated in an environment with aggressive gases, high temperature and dust, it is necessary that the motor is not affected by the environment. The AC motors have also an advantage compared with the DC motors as the AC motor is able to resist an aggressive environment. A DC motor in an aggressive environment needs more maintenance because oil, dust and chemical vapours have a negative impact on the performance of the commutator bar and brushes.

● Improve the extruder with a square frame AC motor:



A square frame AC motor is a compact asynchonous motor which has a considerably smaller physical size than a standard AC motor. Therefore, it is easier to replace a DC motor with a square frame AC motors as they often have almost the same mechanical size. A square frame AC motor has better dynamic torque characteristics than a standard AC motor.
Another good feature by square frame motors is that they have a higher break-down torque than normal asynchronous motors. Especially in the field weakening range a square frame motor has a higher break-down torque.
It is possible to have square frame AC motors with a built-in encoder and with an IP 55 enclosure rating.

■ VLT 5000 Control principle

The VLT 5000 Series features an inverter control system called VVC^{plus}.
VVC^{plus} controls an induction motor by energizing it with a variable frequency and a voltage to match it. If the motor load is changed, the magnetisation of the motor changes too, and so does its speed. Consequently, the motor current is measured continuously and the actual voltage requirements of the motor are calculated from a motor model. Motor frequency and voltage are adjusted to ensure that the motor performance remains best possible under varying conditions.

With the VVC^{plus} the regulation is robust and tolerant to different motor characteristic and motor derating is not necessary.

First and foremost, the current and the motor model calculations are very good. The current is split into magnetising and torque-generating parts and provides for accurate and quick estimation of the actual motor loads. It is thus possible to compensate for rapid load changes. Full torque as well as extremely accurate speed control can be obtained at low speeds or even at standstill.

Good torque control properties, smooth transitions to and from current limit operation and robust pull-out torque protection are ensured.

After automatic motor adaptation, VVC^{plus} will help to ensure extremely accurate motor control.
Advantages of the VVC^{plus} control system:

- Accurate speed control, now even at low speed.
- Quick response from received signal to full motor shaft torque.
- Good compensation for step loads.
- Controlled transition from normal operation to current limit operation (and vice versa).
- Reliable torque protection throughout the speed range, also in the field weakening range.
- High tolerance towards varying motor data.
- Extruder screw protection by limiting the shaft torque.
- Full holding torque (closed loop)

As standard, VLT 5000 Series comes with a number of integral components that would normally have to be acquired separately. These integral components (RFI filter, DC coils, screen clamps and serial communication port) are space-savers that simplifying installation, since VLT 5000 Series fulfils most requirements without any supplementary components.

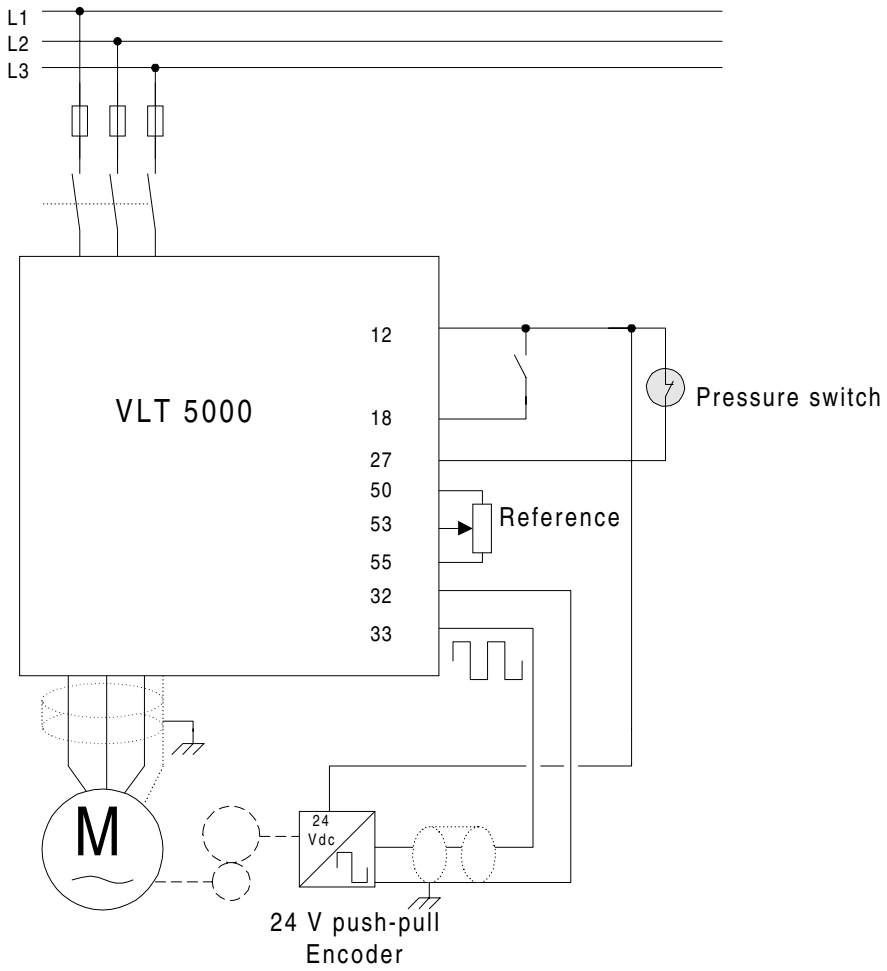
An extruder application with VLT 5000 encoder feedback has the following speed accuracy:

Frequency range:	0 - 1000 Hz
Resolution on output frequency:	±0.003 Hz
Speed accuracy (closed loop):	< 1500 rpm: max deviation ±1.5 rpm

■ Typical wiring example for an extruder application

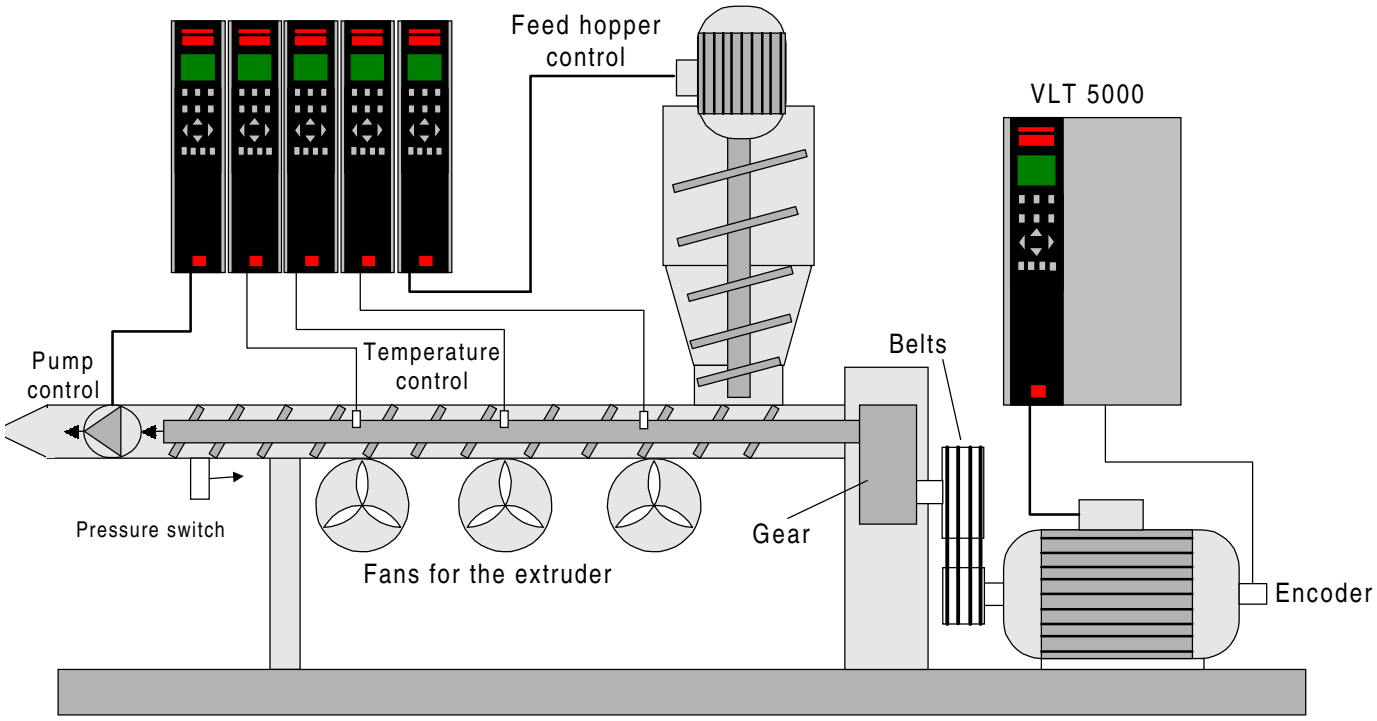
This example shows an extruder application with encoder feedback and a pressure switch that stops the extruder if the pressure gets to high.
Here the VLT 5000 is set to *Speed control, closed loop* in parameter 100 *Configuration*. With an encoder of 1024 pulses/rev you will have full torque and accurate speed control at low speed.

The maximum torque on the extruder can be set in parameter 221 *Torque limit*. A warning or alarm can be displayed on the LCP or via the output relay if the torque exceeds over the torque limit. As it is set to torque limit you can avoid an overload on the extruder.



Function:	Parameter:	Setting:	Data value:
Activation of Speed regulator	100	Speed control, closed loop	[1]
Quick stop ramp-down time	212	1 sec.	
Digital input, terminal 27	304	Quick stop inverse	[1]
Digital input, terminal 32	306	Encoder feedback input B	[24]
Digital input, terminal 33	307	Encoder feedback input A	[25]
Encoder feedback, pulse/rev.	329	1024 pulses/rev.	[1024]
Minimum feedback	414	0 rpm	
Maximum feedback	415	1650 rpm (max. ref. + 10%)	
Proportional gain	417	Application-dependent	
Integration time	418	Application dependent	
Differentiation time	419	Application dependent	

Other applications in extruder systems



Other applications in an extruder systems which can be controlled with Danfoss VLT frequency converters are temperature control in the extruder, pump control and feed hopper control.

It is important to keep the correct temperature in the extruder through the process, and the control of the temperature is often done with fans. The temperature sensors can be connected as a feedback signal to the VLT frequency converter and the temperature will be controlled to a fixed setpoint.

A high output stability is difficult to achieve, as the extruder has some limitations. So the best way to improve the output stability is to add a gear pump to the extruder. The pump is placed between the extruder and the die. The speed of the pump can be controlled precisely by a VLT frequency converter.

The feed hopper holds the plastic pellets or powder and discharges the material into the feed section. A VLT frequency converter can control the feed hopper so that the material has a steady flow through the feed hopper and down to the feed section.

Benefits overview for AC drives (VLT 5000):

- Less costs of maintenance
- Energy savings
- Higher efficiency on AC motors
- Higher starting torque
- Better dynamics
- Can be installed in aggressive environments (gasses, dust etc.)
- AC motors are cheaper than DC motors
- Low harmonic current distortion
- AC systems are easier to install and commission.