Variable speed compressor capacity control

A clear trend in the area of compressor capacity control has become visible in recent years. Compressors are increasingly being used in combination with frequency converters to achieve continuously variable speed control. Here it turns out that it is essential to use compressors that are suitable for operation with speed control.

This is not especially surprising, but it does pose certain difficulties with regard to oil management, electrical loading and mechanical loading.

However, the frequency converter should also be matched to the refrigerant compressor. For example, starting up a compressor under back pressure is a difficult task for a standard frequency converter because the full motor torque is required right from the start. This requirement is not present in standard frequency converter applications, such as speed control of pumps or fans.

**Optimal partial-load capability**

Compressors used in refrigeration systems are normally designed only for the maximum system load. However, systems actually run under partial load during 65% of their operating time, which means that the compressor is oversized for extended periods.
Conventional control systems use an on/off controller, pressure-guided pack-controller, or hot gas bypass controller to compensate for this excess compressor capacity. Compared with these methods, the combination of a compressor and a frequency converter provides superior control performance and higher energy efficiency.

The cooling capacity of a conventional hermetic piston compressor is constant; the motor and crankshaft turn at 2,900 rpm (with a two-pole induction motor and 50 Hz mains frequency). By contrast, with a VTZ Compressor Drive™ the speed can be varied by adjusting the frequency over a range of 30 to 90 Hz. Depending on the necessary cooling load, this yields a motor speed range of 1,800 to 5,400 rpm. As a result, the compressor capacity can always be matched to the cooling demand. The VTZ unit therefore provides the same minimum partial load capacity as a bank of three compressors, but with continuously variable capacity instead of steps of 33%, 66% and 100%.

**Lower starting current**

A compressor connected directly to the AC mains usually draws up to eight times its rated current during start-up. Even with relatively low power ratings, this can lead to interesting discussions with the electricity provider, which will either demand additional technical measures to limit the current or impose a higher tariff for supplying electricity.

The VTZ Compressor Drive™ has a built-in soft starter that reduces peak currents during compressor start-up to levels considerably lower than with direct start-up. The frequency converter initiates compressor start-up at a very low frequency and matches the frequency to the actual rotational speed of the rotor. By contrast, with direct compressor start-up the supply voltage is applied immediately at 50 Hz, even though the rotor has not even started to move. This leads to high starting currents, which are avoided with frequency converter operation.
An additional motor protector switch to monitor the operating current and balanced current consumption is not necessary, since this monitoring function is also provided by the Compressor Drive™ (CD) frequency converter. With a CD frequency converter, a contactor for the compressor is also unnecessary.

**Special frequency converters and compressors**

Not all frequency converters are suitable for controlling one-cylinder or two-cylinder compressors, due to the variation in shaft torque over the full rotation of the crankshaft. This phenomenon only occurs with compressor control and is not present in other applications, such as pump or fan speed control, and it can lead to operating problems with unsuitable frequency converters. In addition, incorrect configuration of the operating frequency parameters for the start-up ramp can rapidly lead to compressor failure.

In particular, an excessively long ramp can have dramatic consequences for lubrication build-up in the compressor. The proper ramp time is approximately 0.6 seconds. To avoid burdening the commissioning fitter with these details, CD frequency converters are preconfigured for operation with one-cylinder and two-cylinder compressors and the proper start-up ramp settings. This allows the VTZ parameters to be selected directly using the settings menu of the CD unit. As a result, the converter knows automatically how many cylinders the compressor has, and it knows which ramp to use. The VTZ–CD™ package includes a VTZ compressor that is specifically designed for speed control and is a perfect match to the CD frequency converter, which is optimized for use in refrigeration systems.

**Cabling**

Special attention must be given to cable routing and shielding when a frequency converter is used. The motor cable (from the converter to the compressor) must always be routed separately from the control and bus lines, and even from the mains cable. In addition, the motor cable in particular should be kept as short as possible. Otherwise EMC problems can easily arise, which may affect the operation of the control electronics or generate interference on the bus lines.
The motor cable must be a shielded cable, with the shield connected to the equipment at each end (the frequency converter and the compressor). More specifically, the insulation should be removed from the shield all round and a metal clamp should be used to connect the shield to the equipment.

The motor cable must be routed at least 200 mm away from the control or bus lines and the mains cable. The mains cable must also be routed so that it is not immediately next to non-power cables. Special attention must also be given to the motor cable if it needs to be de-energized. The power stage of a frequency converter contains capacitors with large storage capacity, which means that hazardous voltages may still be present on the motor cable for a certain length of time after the mains voltage has been switched off.

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**Warning**

- **Switched off**
- **Wait** 15 Min

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**Control using a pressure sensor**

In combination with a pressure sensor, the package operates in approximately the same way as a pack-controller. The frequency converter receives a pressure reference and attempts to maintain a constant pressure at this level. If the pressure level rises, the compressor speed is increased. If the actual pressure drops, the speed is reduced. A very uniform suction pressure can be achieved with this type of control.
Pressure sensors with standard 4–20 mA output (current signal) or 0–10 V output (voltage signal) can be used, as well as special versions with a 1–5 V voltage signal. The frequency converter has a DIP switch for selecting either the factory default pressure sensor setting (voltage signal) or the current signal setting.

**Reference from an external controller**

If a reference for the compressor speed is to be provided by an external controller, the CD unit can also be operated with this reference. A pressure transducer is not necessary with this option. It is replaced by the input signal from the external controller. Here again, a standard 0–10 V voltage signal or 4–20 mA current signal can be used. The controller may be a programmable logic controller (PLC) or a pack-controller with an output for a speed-controlled compressor.

In terms of control engineering, operation with a pack-controller can yield very elegant control results. For example, a three-compressor package consisting of two direct-start compressors and a VTZ–CD combination will start initially with the VTZ unit at light loads. When the VTZ unit is operating at full speed, the pack-controller cuts in another compressor and ramps the VTZ unit back down to its minimum speed (30 Hz). If the suction pressure continues to rise, the VTZ unit again ramps up to maximum speed until finally the last compressor is cut in and the VTZ is again ramped down. This option provides a stable suction pressure similar to the result obtained with a larger speed-controlled compressor operating by itself.

Attention must be given to oil management when a speed-controlled compressor is connected in parallel with direct-start compressors. The maximum number of compressors connected in parallel should not exceed three. Oil level controllers are also essential with such parallel configurations.
Commissioning

It doesn’t take long to commission a VTZ–CD package.
The package is preconfigured in the factory, so only a few settings need to be made when the system is put into service. Critical settings, such as the start-up ramp or important motor characteristics, are protected against inadvertent changes, and they are all stored under the corresponding VTZ parameters in the frequency converter.
A control unit with a graphic display, which is normally located on the front panel of the converter and can be removed if necessary, is used to adjust the parameter settings. The CD unit settings can be saved as a set and transferred to a different CD unit using the operator panel.
**Preview**

In addition to the variable-speed compressors discussed in this issue, which are used in commercial refrigeration, there are compressors with lower capacity and compressors for use in mobile systems. These compressors are usually designed for DC operation, and many of them have adjustable speed. See the next issue for more information on BD compressors for DC operation.