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Application Engineering Europe

USE OF INVERTERS WITH DWM COPELAND™ COMPRESSORS

1 Introduction

Inverters are used to vary the speed of motors and in this way can be used to control the capacity of a compressor. For refrigeration users they can be an effective method of accurately matching compressor capacity to load requirement. A way of reducing compressor output is needed in almost every application. With the emphasis today on saving energy by reducing head pressures, an effective capacity control method can bring enormous benefits. Without the means to run efficiently at low capacity, compressor cycling by switching on/off is most commonly used. This method introduces large fluctuations and high power consumption due to heavily loaded heat exchangers. Multiple compressor solutions overcome this problem to some extent and stepping by means of cylinder unloading is used with piston compressors.

The advantages of varying compressor speed are:

- the load is more closely matched with minimal variation in evaporating pressure and fluctuations in load temperature are minimised;
- better system efficiency at part load;
- extended lifetime of equipment due to continuous operation instead of cycling;
- low starting current obviates the need for assisted start devices;
- with gradual speed increase from standstill there is less risk of sudden liquid or oil return to the compressor on start up.

The objective of this bulletin is to provide technical guidelines to developers, designers or installers that intend to use inverters in refrigeration equipment with DWM Copeland™ semi-hermetic compressors. The operation of an inverter, the effect on compressor application range, performance and power, precautions and some implications on system design are discussed.

2 Operation of an inverter

An inverter works by converting the input mains alternating current to direct current and, from this, regenerating a simulated AC signal at the required frequency. A compressor driven by a squirrel cage motor will run at a speed corresponding to the frequency. The speed will be in direct proportion to the frequency.

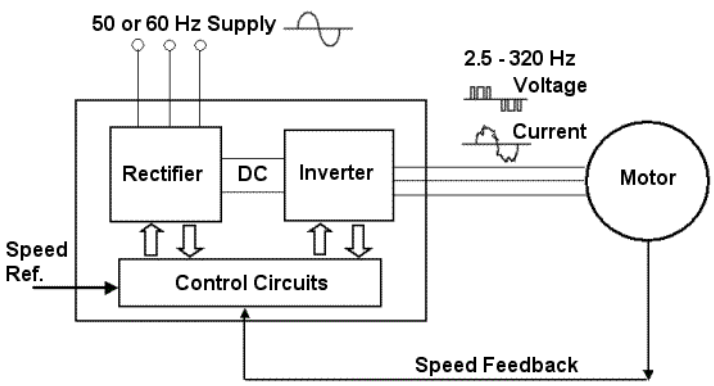

Figure 1

3 Evaluation and important considerations

Most inverters are capable of generating frequencies from 2.5 Hz to over 300 Hz. This is well outside the range of any refrigeration compressor; care must be taken to respect the approved frequency range.

Limits arise due to the capability of the oil pump to maintain lubrication at low speed and motor cooling. Excessive losses at high speeds can result in inefficient operation and overheating (high discharge temperatures).

The power absorbed by a compressor operating with an inverter will always be more than for a direct connected compressor running at the same speed. It is important to choose a high quality inverter because the inverter absorbs a certain amount of power and also the nature of the electrical waveform at the motor is disjointed, resulting in increased motor losses.

When considering an inverter drive the following points should be taken into account:

- loss of efficiency unless care is taken with system design and control;
- conventional capacity control methods may not be used with inverter drive;
- vibration resonance may occur at certain speeds and these are very difficult to predict;
- restrictions on operating envelope may be necessary;
- risk of electrical disturbance to control signals.

4 Limits of use with Copeland® brand compressors

With many inverters it is very easy to alter the maximum and minimum output frequencies and the frequency range, so care must be taken to ensure the frequencies are correctly adjusted to prevent serious damage to the compressor.

***NOTE:* In most variable frequency drives, it is possible to program "skip" frequencies to avoid vibration resonance that may occur at certain speeds.**

4.1 Approved frequency ranges with standard motors

Model family	Speed range
DK*, DL*, D2D*, D2S*, D3D*, D3S*, D4D*, D4S*, D6D*, D6S*, D8D*, D8S*	25 - 60 Hz

Table 1

4.2 Operating 50 to 60 Hz with standard motors

The output voltage from the drive cannot exceed the input voltage to the drive. Most Copeland® brand compressors are designed to operate at 60 Hz speeds as they are marketed in areas where this is the mains supply frequency. Therefore they can safely and reliably operate at this frequency. However it must be noted that when connected to a 400V 50 Hz supply the inverter can only deliver a maximum voltage of 400V. The standard motor requires a higher voltage at 60 Hz. In the range between 50 and 60 Hz the amps could increase and therefore reduce the envelope, such as shown in the following envelopes for the D4D*, D6D* and D8D* Discus compressor models for R404A and R134a.

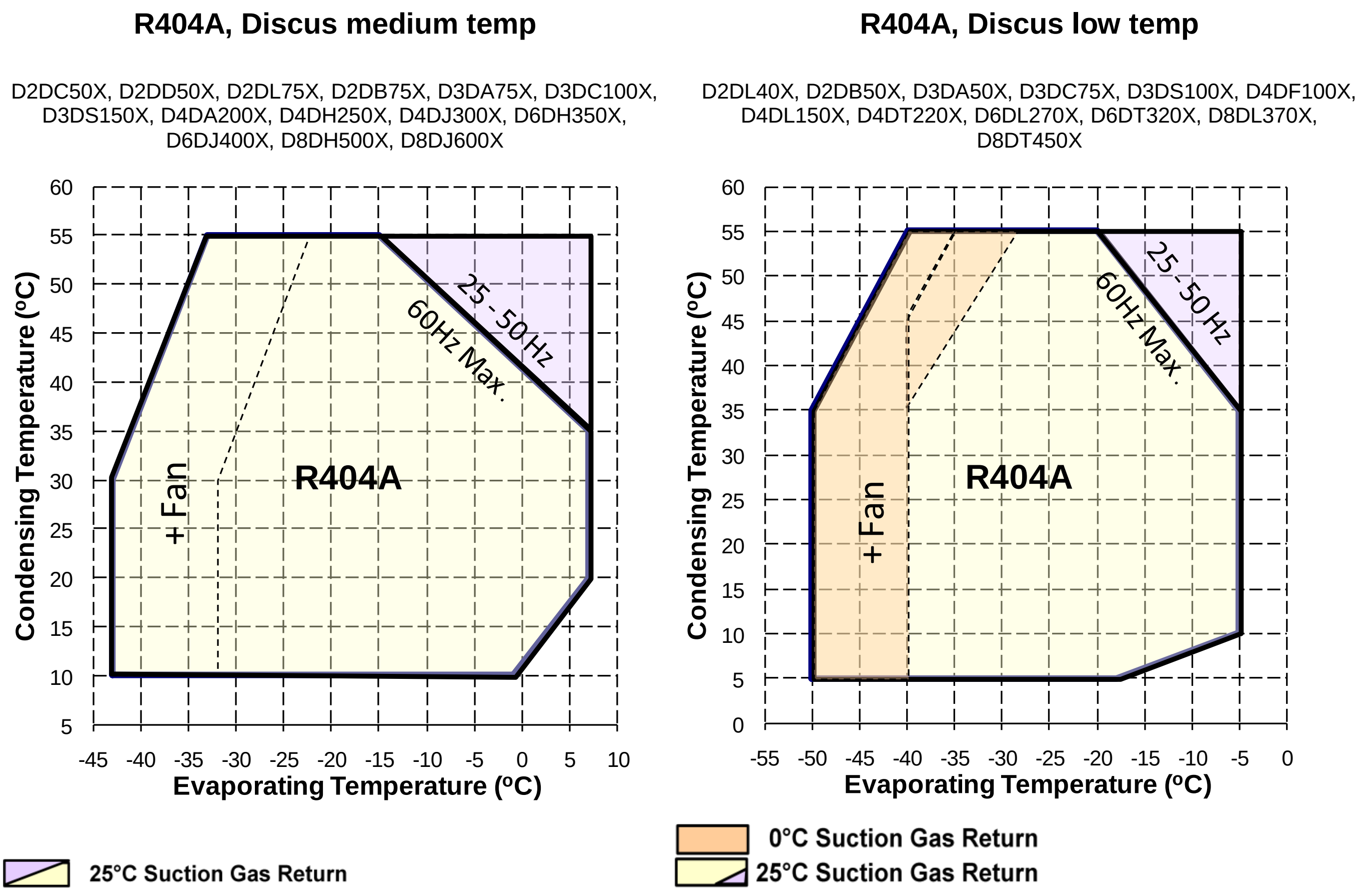

Figure 2: Inverter operation with standard motor 25 to 60 Hz – R404A

R134a, Discus medium temp

D2DL75X, D2DB75X, D3DA75X, D3DC100X, D3DS150X, D4DA200X, D4DH250X, D4DJ300X, D6DH350X, D6DJ400X, D8DH500X, D8DJ600X

R134a, Discus low temp

D2DL40X, D2DB50X, D3DA50X, D3DC75X, D3DS100X, D4DF100X, D4DL150X, D4DT200X, D6DL270X, D6DT320X, D8DL370X, D8DT450X

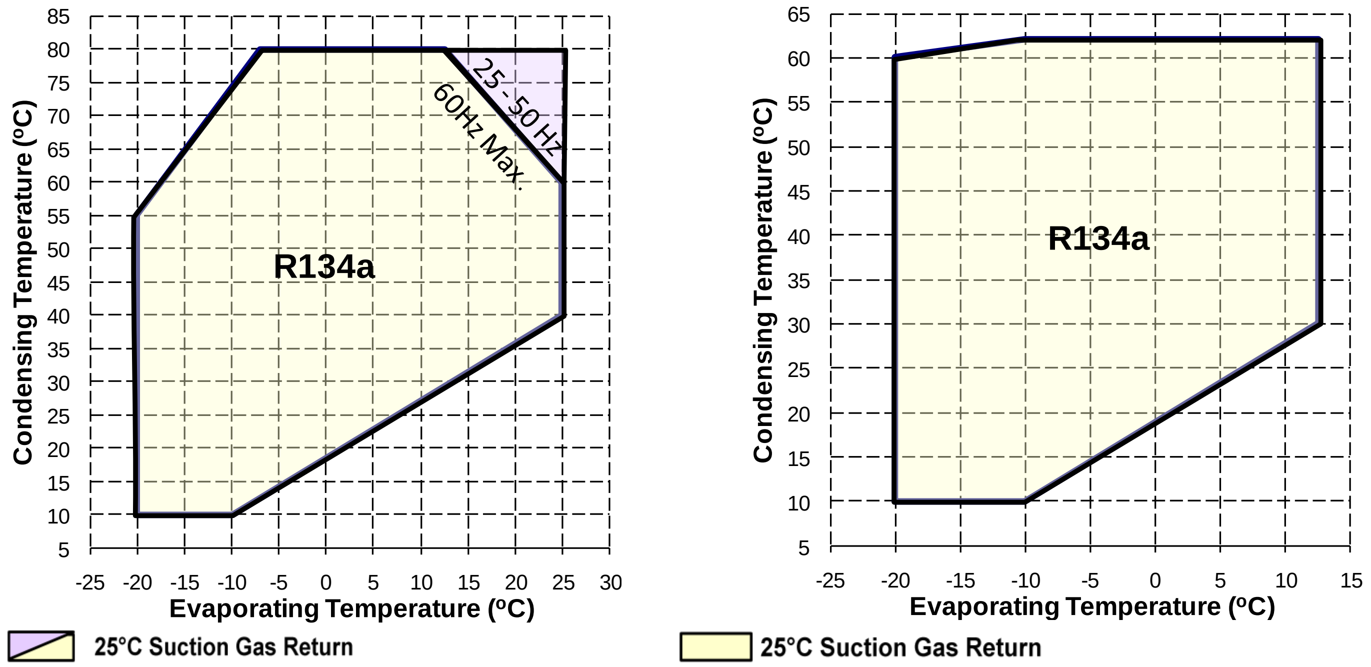

Figure 3: Inverter operation with standard motor 25 to 60 Hz – R134a

4.3 Minimum speed

The minimum allowable frequency of 25 Hz is governed by the lowest speed at which the lubrication system can operate effectively.

4.4 Over-speed with special motors

By using a motor designed for a voltage lower than 400V/50 Hz, in conjunction with a 400V supply, it is possible for the inverter to increase the voltage during over-speed. Normally the ratio of voltage/frequency (V/f) is kept constant, and it is only when the required voltage is above the supply voltage that the amps increase. For example, a 380V/60 Hz motor will only require 320V at 50 Hz according to the constant V/f rule, and can therefore be safely operated at all conditions up to 60 Hz with a suitable inverter. By moving to 230V/50 Hz motor, the scope for increased voltage speed is even greater.

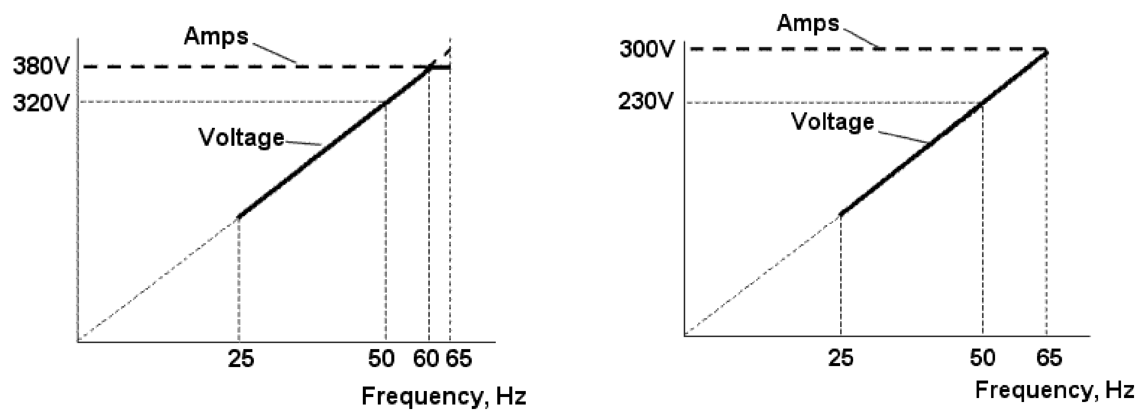

Figure 4

It is important to note that when using special motors in this way there is no option of running direct-on-line in the event of inverter failure.

5 Control of inverter frequency

The signal necessary to control the inverter depends on the type of inverter used. They are normally controlled by a 4 to 20 mA or a voltage signal. This can be driven from the parameter which is used to control the refrigeration system, for example suction pressure or room temperature.

6 Power measurement and cable sizing

The inverter can cause distortion of the sinusoidal current waveform, and between the inverter and the motor there is a stepped current approximating to a sine wave. High-quality inverters will introduce less distortion and power losses. Power can be measured using the two wattmeter method on the input to the inverter.

Currents can exceed the amounts calculated from this power. Cables, fuses and contactors will need to be sized for the true RMS current flowing through them. General rules for this are:

- cable from motor to inverter - size for 10% more current than standard;
- cable from inverter to mains - size for 20% more current than standard.

7 Start contactor positioning

The inverter should not be allowed to operate with the output from the inverter to the motor open circuit. There should be a contactor each side of the inverter, ie, between the inverter and the mains and between the inverter and the compressor motor. They should be interlocked to break the mains side first. When switching on, the motor side contactor should be made first.

When using an inverter bypass, care should be taken to ensure there can be no voltage feedback to the inverter. Therefore when the bypass contactor is closed and the bypass is in operation, the contactors on either side of the inverter must be open.

8 Starting and ramp-up

An inverter is capable of delivering a soft start, but at the same time care must be taken to ensure that stalling does not occur. The inverter must be able to deliver sufficient power at the lower frequencies to ensure that the compressor accelerates to nominal speed in approximately 3 seconds or less. Only general guidance can be given here, because the exact torque requirements will depend on system pressures at the time of start up. Longer ramp-up times could result in inadequate lubrication. It may be necessary to set the inverter to deliver a slightly increased voltage (compared to the normal V/f rule in Section 4.4) at the low frequency applicable during ramp-up, but this should not result in deviation from the V/f rule during normal operation.

9 Electrical shielding and voltage rise

Wiring of the electrical enclosure and the installation must be carefully conducted in accordance with EMC recommendations. High quality, high reliable pressure sensors must be used and it is necessary to follow EMC measures to ensure that the inverter does not disturb the signals from pressure transducers. Suction and high pressure sensors signals must be noise-free to the controller input. The inverter itself can be fitted with suitable EMC filters, eg, EN 55011 Class B.

Since the waveform generated by the inverter is built up from pulses, there is a danger that the rate of voltage rise on an individual pulse can be too fast. Generally this is measured in kV per microsecond, and limits at the motor terminals which should be adhered to during the first microsecond are given in EN 60034. In order to minimize the risk of motor problems, it is suggested that the variable frequency drive be operated at its lowest switching frequency and that the distance between the frequency drive and the compressor be as short as possible.

10 Vibration

A compressor running at fixed speed imposes vibrations on its associated framework at a set group of frequencies. The framework can of course be designed so that its natural frequencies differ from the imposed frequencies.

A compressor driven at variable speed will impose different frequencies at each speed, so the framework design to eliminate vibration throughout the speed range is more complex.

The framework structure should be stiff enough so that its resonant frequencies are above the maximum frequency, ie, 60 or 65 Hz. Designing with natural frequencies below the minimum speed of 20 or 25 Hz, could lead to vibration problems during start up. Spring mounts should not be used as they have a natural frequency below 65 Hz.

NOTE: **The system should be designed or the variable frequency drive control should be configured (skip frequencies programmed), so that there is no operation at resonant frequencies between 20 and 70 Hz.**

11 Internally compounded compressors

The operation of internally compounded compressors at variable speed may require the selection of a different liquid injection interstage cooling expansion valve. Please consult Emerson Climate Technologies for further details.

12 Recommended inverter range

Emerson Climate Technologies recommends the use of Control Techniques brand inverter with DWM Standard and Discus compressors.

Please see the corresponding cross reference list in the **Appendix**.

13 Summary

The following is a summary of the main considerations when using inverter drive as capacity control:

- The compressor must not operate outside the range 25 to 60 Hz.
- The compressor application range might be reduced for motor loading, if over-speed is used.
- The capacity of the compressor will be in direct proportion to the speed.
- The power input to the compressor will depend on the efficiency of the inverter and the frequency.
- The framework should be designed such that resonance frequencies are above 65 Hz.
- The system should be designed or the variable frequency drive should be configured (skip frequencies programmed), such that there is no operation at resonant frequencies.
- There are inherent inefficiencies associated with the operation of the inverter.
- Care must be taken when setting up the inverter to ensure it does not operate outside the specified frequency range, and that it operates at maximum efficiency.
- Cable sizing from the mains supply and to the compressor motor must be sized to account for higher currents than for a similar size system without inverter.
- The control circuit should be designed such that the inverter cannot operate with the output from the inverter to the motor open circuit.
- Reduced gas velocities at lower speed may necessitate re-design of discharge and suction pipe work.

Appendix - Cross reference list

DWM compressors and corresponding inverters from Control Techniques

Control Techniques inverter product range: Commander SK

Compressor	Control Techniques Inverter Commander SK	Compressor	Control Techniques Inverter Commander SK	Compressor	Control Techniques Inverter Commander SK
DKM-5X	SKB3400110	D2SC-65X	SK2403	D6SJ-300X	SK4401
DKM-7X	SKB3400150	D2DB-50X	SK2403	D4SJ-300X	SK4401
DKJ-7X	SKB3400220	D3DA-50X	SK2403	D8SH-400X	SK4401
DKJ-10X	SKC3400220	D3DC-100X	SK2403	D4DJ-300X	SK4401
DKSJ-10X	SKC3400220	D2SK-75X	SK2403	D4ST-200X	SK4401
DKSJ-15X	SKC3400220	D3SC-100X	SK2404	D4DT-220X	SK4401
DKL-20X	SKC3400220	D2SK-65X	SK2404	D6SK-400X	SK4402
DKSL-15X	SKC3400300	D3DC-75X	SK2404	D6DH-350X	SK4402
DKL-15X	SKC3400300	D3SC-75X	SK2404	D6SH-350X	SK4402
DKSL-20X	SKC3400300	D4SH-150X	SK2404	D6DL-270X	SK4402
DLF-20X	SKC3400400	D3DS-100X	SK3401	D6SL-250X	SK4402
DLE-20X	SKC3400400	D4SA-200X	SK3402	D8SJ-500X	SK4403
DLJ-20X	SKD3400550	D4DA-200X	SK3402	D6DT-320X	SK4403
DLF-30X	SKD3400550	D3DS-150X	SK3402	D6SJ-400X	SK4403
DLJ-30X	SKD3400550	D4DF-100X	SK3402	D6ST-320X	SK4403
DLL-30X	SKD3400550	D3DS-100X	SK3402	D6ST-300X	SK4403
D2DC-50X	SKD3400550	D4SF-100X	SK3402	D8SH-370X	SK4403
DLL-40X	SKD3400550	D3SS-150X	SK3402	D6DJ-400X	SK4403
D2DD-50X	SKD3400750	D4SJ-200X	SK3402	D8DH-500X	SK4403
DLSG-40X	SKD3400750	D4SL-150X	SK3402	D8SK-600X	SK4403
D2SA-55X	SK2403	D3SS-100X	SK3402	D8DL-370X	SK4403
D2DL-40X	SK2403	D6SH-200X	SK3403	D6SK-500X	SK4403
D2DL-75X	SK2403	D4DH-250X	SK3403	D8SH-500X	SK4403
D2SA-45X	SK2403	D4SH-250X	SK3403	D6SU-400X	SK4403
D3DA-50X	SK2403	D6SF-200X	SK4401	D8SJ-600X	SK5401
D3DA-75X	SK2403	D4DL-150X	SK4401	D8DJ-600X	SK5401
D2SC-55X	SK2403	D4SL-150X	SK4401	D8DT-450X	SK5401
D2DB-75X	SK2403	D6SA-300X	SK4401	D8SJ-450X	SK5401
D3SA-75X	SK2403				

Table 2