Application Engineering

Transpo Use of Variable Frequency Drives (VFDs) With Copeland Scrolland Copeland Discus Fixed Capacity Compressors in Refrigeration Applications

BULLETIN NO: AE21-1369 R7

Contents

COPELAND

Safety

Important Safety Information

Those involved in the design, manufacture, and installation of a system, system purchasers, and service personnel may need to be aware of hazards and precautions discussed in this section and throughout this document. OEMs integrating the compressor into a system should ensure that their own employees follow this bulletin and provide any necessary safety information to those involved in manufacturing, installing, purchasing, and servicing the system.

Responsibilities, Qualifications and Training

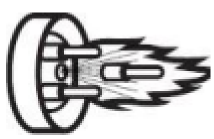
• OEMs are responsible for system design, selection of appropriate components, integration of this component into the system, and testing the system. OEMs must ensure that staff involved in these activities are competent and qualified.

• OEMs are also responsible for ensuring that all product, service, and cautionary labels remain visible or are appropriately added in a conspicuous location on the system to ensure they are clear to any personnel involved in the installation, commissioning, troubleshooting or maintenance of this equipment.

• Only qualified and authorized HVAC or refrigeration personnel are permitted to install, commission, troubleshoot and maintain this equipment. Electrical connections must be made by qualified electrical personnel.

• Observe all applicable standards and codes for installing, servicing, and maintaining electrical and refrigeration equipment.

Terminal Venting and Other Pressurized System Hazards



If a compressor's electrical terminal pin loses its seal, pressurized oil, refrigerant, and debris may spray out. This is called "terminal venting".

The ejected debris, oil, and refrigerant can injure people or damage property. The oil and refrigerant spray can be ignited by electrical arcing at the terminal or any nearby ignition source, producing flames that may project a significant distance from the compressor. The distance depends on the pressure and the amount of refrigerant and oil mixture in the system. The flames can cause serious or fatal burns and ignite nearby materials.

Each compressor has a terminal cover or molded plug that covers electrical connections. The cover or plug helps to protect against electric shock and the risks of terminal venting. If terminal venting occurs, the cover or plug helps contain the spray of refrigerant and oil and reduces the risk of ignition. If ignition occurs, the plug or cover helps contain the flames. However, neither the terminal cover nor the molded plug can completely eliminate the risk of venting, ignition, or electric shock.

See copeland.com/terminal-venting for more details about terminal venting. Additionally, a compressor's refrigerant lines keep refrigerant and oil under pressure. When removing or recharging refrigerant from this component during service, this can pose a pressurized fluid hazard.

Flammable Refrigerant Hazards

If flammable refrigerant is released from a system, an explosive concentration can be present in the air near the system. If there is an ignition source nearby, a release of flammable refrigerant can result in a fire or explosion. While systems using flammable refrigerant are designed to mitigate the risk of ignition if the refrigerant is released, fire and explosion can still occur.

See copeland.com/flammable-refrigerants for more information on flammable refrigerant safety.

Electrical Hazards

Until a system is de-energized, and capacitors have been discharged, the system presents a risk of electric shock.

Hot Surface and Fire Hazards

While the system is energized, and for some time after it is deenergized, the compressor may be hot. Touching the compressor before it has cooled can result in severe burns. When brazing system components during service, the flames can cause severe burns and ignite nearby combustible materials.

Lifting Hazards

Certain system components may be very heavy. Improperly lifting system components or the compressor can result in serious personal injury. Use proper lifting techniques when moving.

POE Oil Hazards

This equipment contains polyol ester (POE) oils. Certain polymers (e.g., PVC/CPVC and polycarbonate) can be harmed if they come into contact with POE oils. If POE oil contacts bare skin, it may cause an allergic skin reaction.

Precautions

• Always wear personal protective equipment (gloves, eye protection, etc.).

• Keep a fire extinguisher at the jobsite at all times.

• Keep clear of the compressor when power is applied.

> - IMMEDIATELY GET AWAY **if you hear unusual sounds in the compressor. They can indicate that terminal pin ejection may be imminent. This may sound like electrical arcing (sizzling, sputtering or popping). However, terminal venting may still occur even if you do not hear any unusual sounds.**

• Never reset a breaker or replace a blown fuse without performing appropriate electrical testing

- **A tripped breaker or blown fuse may indicate an electrical fault in the compressor. Energizing a compressor with an electrical fault can cause terminal venting. Perform checks to rule out an electrical fault.**

• Disconnect power and use lock-out/tag-out procedures before servicing.

- Before removing the terminal cover or molded plug, check that ALL electrical power is disconnected from the unit. Make sure that all power legs are open. (Note: The system may have more than one power supply.)

- Discharge capacitors for a minimum of two minutes

- Always use control of hazardous energy (lock-out/tag-out) procedures to ensure that power is not reconnected while the unit is being serviced.

• Allow time for the compressor to cool before servicing.

- Ensure that materials and wiring do not touch high temperature areas of the compressor.

• Keep all non-essential personnel away from the compressor during service.

• For A3 refrigerants (R290) remove refrigerant from both the high and low sides of the compressor. Use a recovery machine and cylinder designed for flammable refrigerants. Do not use standard recovery machines because they contain sources of ignition such as switches, high- and low-pressure controls and relays. Only vent the R290 refrigerant into the atmosphere if the system is in a well-ventilated area.

• Never use a torch to remove the compressor. Only tubing cutters should be used for both A2L and A3 refrigerants.

• Use an appropriate lifting device to install or remove the compressor.

• Never install a system and leave it unattended when it has no charge, a holding charge, or with the service valves closed without electrically locking out the system.

• Always wear appropriate safety glasses and gloves when brazing or unbrazing system components.

• Charge the system with only approved refrigerants and refrigeration oils.

• Keep POE oils away from certain polymers (e.g., PVC/CPVC and polycarbonate) and any other surface or material that might be harmed by POE oils. Proper protective equipment (gloves, eye protection, etc.) must be used when handling POE lubricant. Handle POE oil with care. Refer to the Safety Data Sheet (SDS) for further details.

• Before energizing the system:

1. Securely fasten the protective terminal cover or molded plug to the compressor, and

2. Check that the compressor is properly grounded per the applicable system and compressor requirements.

Signal Word Definitions

The signal word explained below are used throughout the document to indicate safety messages.

DANGER indicates a hazardous situation which, if not avoided, will result in death or serious injury.

WARNING indicates a hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION, used with the safety alert symbol, indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

Introduction

Variable frequency drives (VFDs) 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 a load requirement. A method 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 in piston compressors or scroll unloading in digital scroll compressors can be used to match capacity with some system efficiency gain.

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 minimized.
- Better system efficiency at part load.
- Extended lifetime of equipment due to continuous operation instead of cycling.
- Low starting current avoids the need for assisted start devices.
- With controlled 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 VFDs to vary the speed of Copeland Discus and Copeland Scroll compressors, originally designed as fixed-speed compressors, in their refrigeration systems.

Operation of a Variable Frequency Drive

A VFD works by converting the input alternating current to direct current and, from this, generating an alternating current output at varying frequencies. A compressor driven by a squirrel cage induction motor will run at a speed in direct proportion to the fundamental frequency driving the compressor minus a small amount for motor slip.

Evaluation and Important Considerations

Most VFDs can generate frequencies from *2.5* Hz to over *300* Hz. *This is well outside the range of any refrigeration compressor*; therefore, practical limits must be established.

These limits arise from many different aspects of the compressor design including the capability of the oil pump to maintain lubrication at low speed, motor cooling considerations, and increased losses at higher speeds which can result in less efficient operation and compressor overheating (high discharge temperatures).

The steady state power absorbed by a compressor operating with a VFD will always be more than for a direct line-connected compressor running at the same speed. It is important to choose a high quality VFD because the VFD absorbs a certain amount of power, which will lower the system efficiency. Also, the typical pulse width modulated (PWM) waveform output from the VFD to the motor contains high-frequency harmonics, resulting in increased motor losses.

When considering a VFD, 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 a VFD (i.e. blocked suction, or Copeland Digital) on the same compressor.
- Vibration resonance may occur at certain speeds, and these are very difficult to predict.
- Risk of electrical disturbance to control signals due to the high-frequency content of the drive's output waveforms.

Limits of Use with Copeland Fixed-Capacity Compressors

With many VFDs 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 damage to the compressor. See **Table 1** below for the approved operating frequency range for Copeland fixed-capacity Compressors.

Note: In most variable frequency drives, you can also program "skip" frequencies to avoid vibration resonance that may occur at certain speeds.

Table 1: Approved operating range for fixed- capacity Copeland compressors

Model Family	Speed Range	Notes
3D, 4D, & 6D	25 – 60 Hz	
Refrigeration Scroll (ZB, ZS, ZF) other than those listed below.	45 – 60 Hz	
ZB06KAE ZB07KAE ZB08KAE	50 – 60 Hz	
ZRHV72KJE ZBHV45KJE	Per AE4-1343	
ZCH72C3G ZCH72C4G	35 -70 Hz	

Note: Application Engineering Bulletin AE4-1343 should be referenced when applying the ZRHV72KJE and ZBHV45KJE variable speed horizontal Copeland Scroll compressors.

Approved Voltage/Frequency Ranges with Standard Motors

For the compressors listed in Table 1, the ratio of voltage/frequency (V/f) must be kept constant. For example, a 460V 60Hz motor will only require 383V at 50 Hz according to the constant V/f rule and can be safely operated at all conditions over the frequency range given in **Table 1** with a suitable drive. See **Figure 1** for a graphical representation.

Note: On most drives, the output voltage from the drive cannot exceed the input voltage to the drive.

Minimum Speed

CAUTION

The minimum allowable frequency for Discus and scroll compressors is per **Table 1.**

CAUTION

Note: The 2D family of Discus compressors is limited to fixed 50/60 hertz applications. The vibration issues are too severe when running the 2D below 50 HZ.

Effect of the VFD on Performance and Power Input

The compressor capacity can be calculated as being in direct proportion to the speed. A compressor is designed to have optimum pumping efficiency at its nominal speed, usually 1750 RPM for Discus and 3500 RPM for scroll. When operating at speeds other than the nominal, the efficiency of a Discus compressor will change because of the behavior of the valve reeds and the change in pressure drop through the valve plate. However, as these tend to balance out, the change in volumetric efficiency is small.

Control of VFD Frequency

The signal necessary to control the VFD depends on the type of VFD used. They are commonly controlled by an analog 4 to 20 mA signal, a 0-10 Vdc signal or via a serial communication bus. This signal should respond to changes in the system's control variable, for example changes in suction pressure or room temperature.

NOTICE

Copeland strongly recommends controlling from suction pressure because a response to a temperature signal may lag.

Start Contactor Positioning

If a contactor is used to disconnect the VFD from the motor it should be interlocked to only switch when the VFD is off. There should be a contactor on each side of the drive, i.e. between the drive and the supply and between the drive and the compressor motor. They should be interlocked to break the supply side first. When switching on, the motor side contactor should be made first. contactor on each side of the drive, i.e. between the drive and the supply and between the drive and the compressor motor. They should be interlocked to break the supply side first. When switching on, the motor side contactor should be made first.

When using a VFD bypass, care should be taken to ensure there can be no voltage feedback to the VFD. Therefore, when the bypass is in operation, the contactors on either side of the VFD must be open. The contactors should be coordinated such that the VFD contactors open before the bypass contactor closes.

Starting and Ramp Up

A VFD is capable of delivering a soft start, but care must be taken to ensure that stalling does not occur. The VFD must be able to deliver sufficient power at the lower frequencies to ensure that the compressor accelerates to nominal speed in 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.

CAUTION

Longer ramp up times could result in inadequate lubrication.

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 reliability pressure sensors must be used, and it is necessary to follow EMC measures to ensure that the VFD does not disturb the signals from pressure transducers. Suction and high-pressure sensor signals must be noise-free to the controller input. For best results select a VFD with a built-in EMC filter or add the manufacturer's recommended optional filter if it is not a standard component.

Because the pulse-width modulated (PWM) waveform generated by the VFD is built from high-frequency pulses, there is a danger that the rate of voltage rise on an individual pulse could damage the motor insulation system. To minimize the risk of motor problems it is suggested that the VFD be operated at the lowest switching frequency that gives adequate performance. The recommended switching frequency range for the VFD is 2 to 3 kHz. Higher switching frequencies result in higher losses that lower efficiency and can cause motor overheating. See **Figure 2.**

Regardless of chosen switching frequency, VFDs used to power Copeland compressors must comply with the provisions of IEC Technical Specification 60034-17. In particular, the motor input voltage must meet the limiting curve of admissible impulse voltage (1.35 kV/microsecond curve). These provisions are required to avoid motor insulation breakdown, to limit motor heating, and to prolong motor life.

In addition, good design practice is to keep the distance between the VFD and the compressor as short as possible. The maximum allowable wire length is affected by the switching frequency, wire capacitance and output filtering built into the VFD. Please consult the VFD manufacturer’s documentation for determining the allowable wire length. Additionally, the wiring between the VFD and the compressor can generate radiated emissions (electrical noise). Therefore, the system designer should take care to locate control wires away from these power wires. It may be possible to shield the wires from the VFD to the compressor or apply an EMI filter to minimize the radiated noise. Please consult the VFD manufacturer’s documentation for more information on shielding, filters and other EMC measures.

Vibration

A compressor running at fixed speed imposes vibrations on its associated framework at a set group of frequencies.

The framework can be designed such that its natural frequencies differ from the imposed frequencies.

A compressor driven at variable speeds 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 such that its resonant frequencies are above the maximum compressor frequency. Designing with natural frequencies below the minimum speeds called out in **Table 1** could lead to vibration problems during start up. Spring mounts should not be used as they have a natural frequency below 65 Hz. As a rule of thumb, the system should be designed or the VFD control should be configured (skip frequencies programmed), such that there is no operation at any resonant frequencies between 20 and 60Hz.

Typical VFD Parameter Set Up for Discus and Scroll Refrigeration Compressor

The following is a list of some recommended control parameters for configuring a VFD.

- minimum frequency per **Table 1.**
- maximum frequency per **Table 1.**
- 3 sec Acceleration ramp to nominal 60 Hz (20 Hz/second) at startup to ensure lubrication.
- Motor rated current (A) per compressor data sheet. Typically used for current limit protection.
- Motor Rated Speed: Recommend setting this to synchronous speed to disable slip compensation on drives with this feature. It can be set to nameplate rated speed to enable slip compensation, but the user must verify current increase is not excessive.
- Motor rated voltage per nameplate.
- 2 - 3 kHz Switching frequency.
- Motor rated frequency per nameplate drives with this feature. It can be set to nameplate rated speed to enable slip compensation, but the user must verify current increase is not excessive.
- Motor rated voltage per nameplate.
- 2 - 3 kHz Switching frequency.
- Motor rated frequency per nameplate.
- Open loop V/f (V/Hz) control mode.
- Impulse voltage (slew rate) of PWM waveform complies with IEC Technical Specification 60034-17 limit of 1.35 kV / microsecond maximum.

Note that other parameters will need to be adjusted to match the control method and frequency set point input type used.

Contact your Application Engineer for additional information related with your specific application design.

General Guidelines and More Information

For general Copeland Scroll compressor information please log in to Online Product Information at Copeland OPI or contact your Application Engineer. For information on other Copeland Brand variable speed compressors, please refer to the Application Engineering bulletins below.

AE4-1343	**ZRHV72KJE and ZBHV45KJE Variable Speed Horizontal Copeland™ Scroll Compressors**
AE4-1407	**ZPV021*E – ZPV041*E and ZHV021*P – ZHV034*P Copeland™ Scroll Variable Speed Compressors**
AE4-1414	**ZPV066 & ZPV096 Copeland™ Scroll Variable Speed Compressors**
AE4-1388	**20 to 40 Ton ZP*KC and ZR*KC Copeland™ Scroll Air Conditioning Compressors**
AE4-1353	**Copeland™ Scroll Horizontal Cryogenic Compressors ZCH22/48/68/72**

Tables and Figures

Figure 1-Voltage-Frequency Relationship

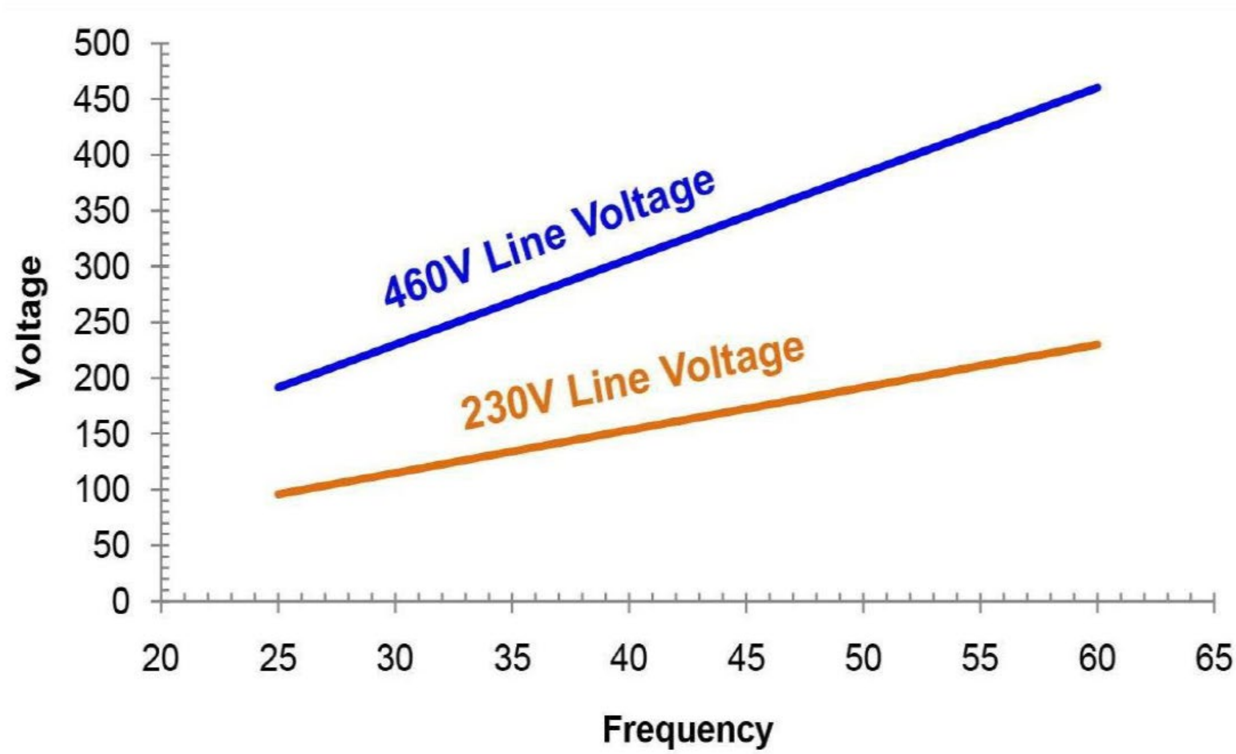
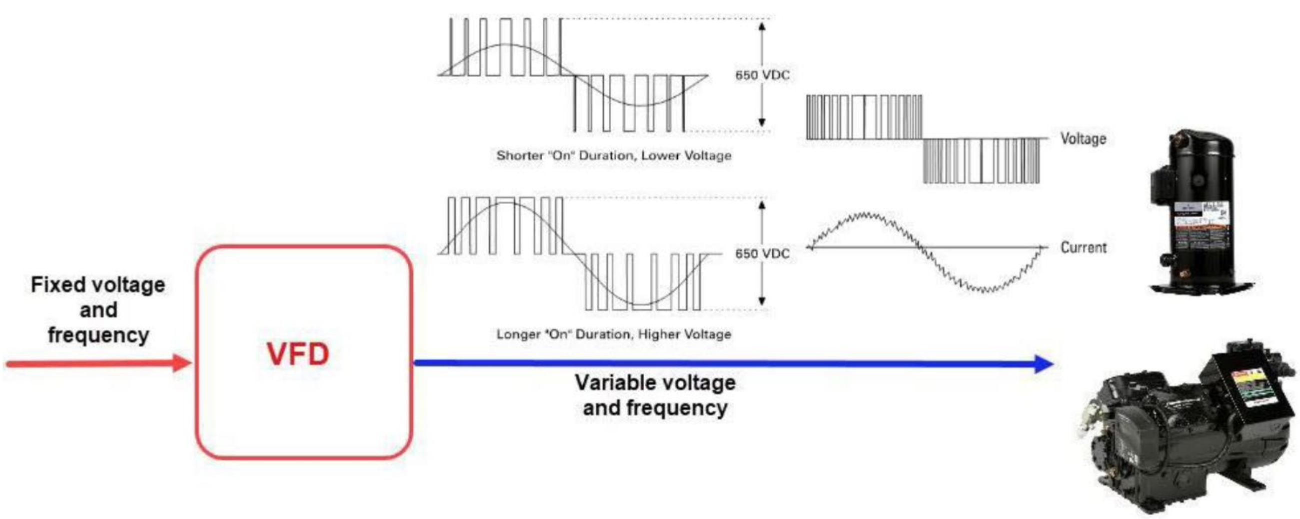


Figure 2 - Utility vs VFD voltage waveform.



Revision Tracking R7

The document format has been updated to the new Copeland format.
All occurrences of "Emerson" have been removed.
A note regarding A3 and R290 venting has been updated.
Removing of number order to the contents.
Update from Emerson.com/OPI to Copeland OPI.