Step-up Autotransformers
Improve the Stable Operation of
Multiple-Compressor Racks (1/4)

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Introduction

Multiple-compressor racks operated with frequency inverters are much more energy-efficient than multiple-compressor racks operated with step control. The capacity ranges of the inverter-driven compressor must therefore be fully utilised. This is often not possible as the maximum operating frequency is limited by the motor current. The achievable operating frequency is therefore lower than the mechanical maximum frequency. The use of a step-up autotransformer to increase the input voltage to the inverter enables the maximum mechanical frequency to be reached.

Star-connected Compressor Motors

In the European three-phase power supply system, the voltage is 400 V at 50 Hz and therefore determines the break frequency of a compressor motor connected in star.

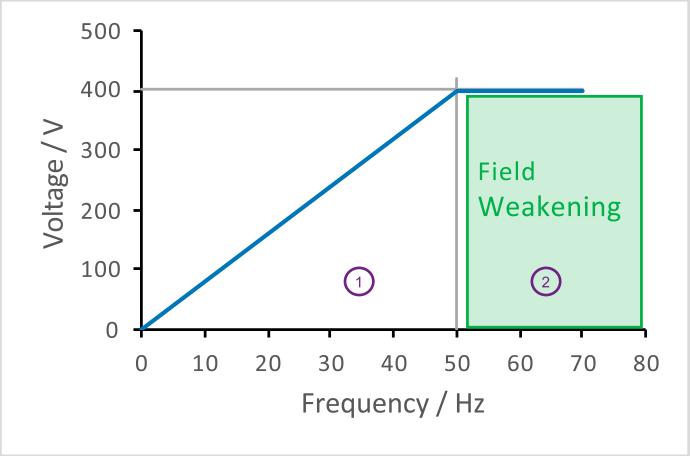

Figure 1: Typical V/f characteristic of a compressor motor connected in star

The following equations apply to every point of the curve when operating with a frequency inverter:

$$M \approx \text{const} \qquad M \sim \Phi \cdot I \qquad \Phi \approx V/f$$

M = Torque of the motor
Φ = Magnetic flux
V = Compressor motor voltage
I = Compressor motor current
f = Compressor frequency

① For operation up to 400 V / 50 Hz (area of constant magnetic flux)
Φ ≈ const, I ≈ const

② Operating above 400 V / 50 Hz (area of field weakening)
V ≈ const, f ↑, Φ ↓, I ↑

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Intelligent Refrigeration Inverters

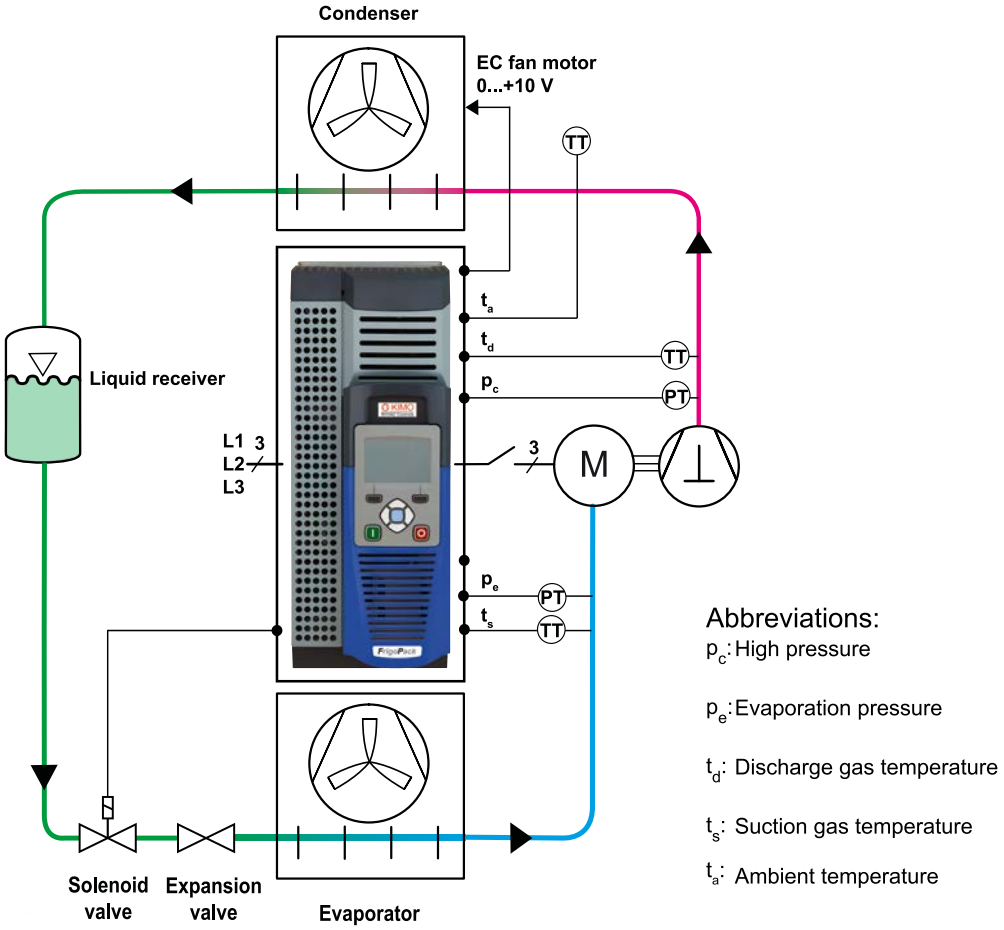

Figure 2: Control functionalities with an intelligent frequency inverter

Frequency inverters are a widely used technology and their range of functionalities is constantly growing:

- Energy efficiency
- Control of the overall system
- Reduced wear of components
- Improved system reliability
- Lower starting currents
- Compensation for wide voltage variations
- Design for higher input voltages

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Stepless Capacity Control

In order to achieve stepless capacity control, the size of the Variable-speed Compressor (VsC) and the Fixed-speed Compressor (FsC) should be selected to fulfil the following equation:

$$Q_{VsC,fmax} - Q_{VsC,fmin} \geq Q_{FsC}$$

$Q_{VsC,fmax}$: Cooling capacity at maximum VsC frequency
$Q_{VsC,fmin}$: Cooling capacity at minimum VsC frequency
Q_{FsC}: Cooling capacity of next step FsC

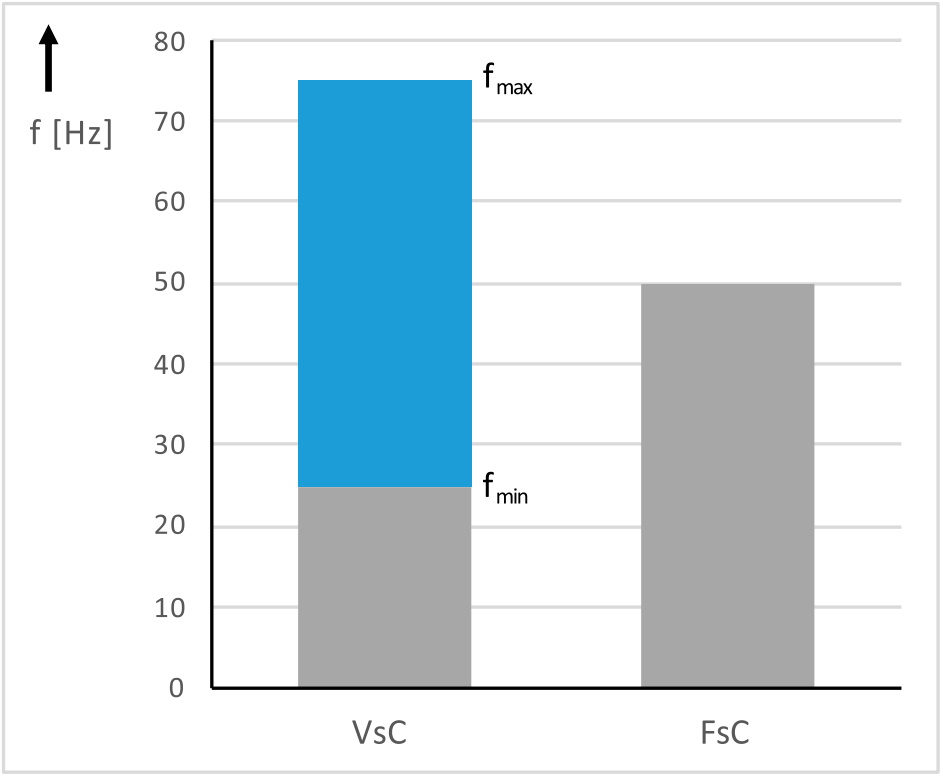

Figure 3: Performance range of two identical compressors in a rack consisting of one VsC and one FsC

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Step-up Autotransformers Improve Control Quality

Figure 4: Electrical step-up autotransformer

Using a step-up autotransformer, the input voltage for the same frequency inverter can be increased by 20 % from 400 V to 480 V. This increase shifts the reaching of the field weakening from 50 Hz to 60 Hz. This also means that the maximum operating current of the compressor is also reached at a 20 % higher frequency. The intelligent frequency inverter used must be designed for the higher input voltages.

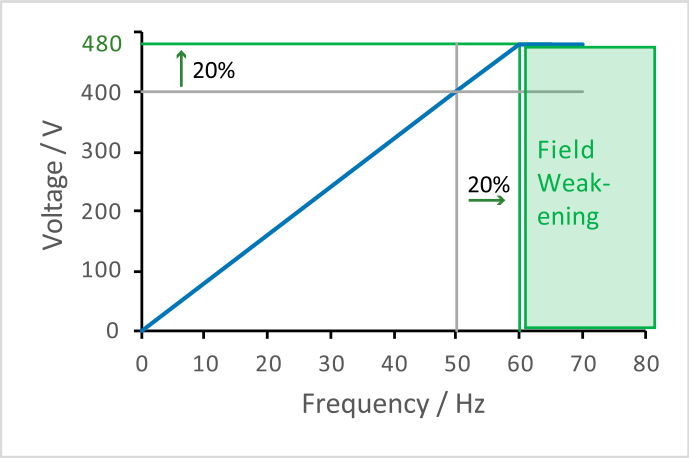

Figure 5: V/f characteristic of a compressor motor connected in star, operated with an electrical step-up autotransformer