Software allows the correct choice of suitable frequency inverters

Selecting frequency inverters for refrigeration compressor control must be conducted with great care, as an inverter selected too small-sized may present some disadvantages. These can be avoided by consulting the FrigoPack-select software by KIMO Refrigeration HVAC Ltd. Based on a process of individual selection and qualifying of the inverter suited for a given refrigeration compressor, safe and energy-saving operation of the compressor can be achieved. **Dr. John P. Gibson, Fürth**

Experiences made in over 20,000 frequency inverter installations in refrigeration and A/C projects have led to a list of priorities for the correct selection of a suitable inverter.

List of priorities for inverter selection

(1) The compressor motor winding must not be overheated. This happens when the starting torque of an inverter dimensioned too small is not sufficient for starting the compressor. The consequence of a stalled start is insufficient cooling of the compressor motor. The winding temperature will then rise quickly and at 120 °C or above it is in danger (see **Fig. 1**).

(2) A stalled starting attempt has to be detected immediately and the inverter inhibited before the winding temperature increases to a critical temperature. Restarting of the inverter must be prevented for a period of at least 1 minute.
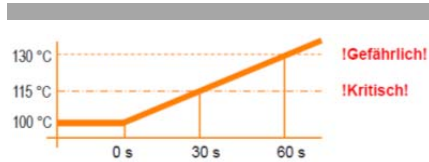

Fig. 1: Temperature rise on stalled start of compressor

(3) With the starting current available, the highest possible starting torque must be achieved. The higher the starting torque, the safer is starting. With the same current, the starting torque of the refrigeration inverters presented hereafter is 20 % higher than that of a conventional frequency inverter intended for industrial use.

(4) Provided the compressor motor is selected correctly with an appropriate reserve in motor size, the maximum frequency of the compressor can be increased to the mechanical limits until the maximum motor current is reached. This enables a high so-called Control Factor (CF) can be reached. The Control Factor is defined as follows:

(5) Achieving the highest possible Control Factor (CF) is important for the following reasons:

- A good CF results in a good control of suction pressure. The suction pressure is stable and the expansion valve can operate well with a high efficiency (i.e. energy-saving), resulting in optimum filling of the evaporator.
- The reduced number of starts of the Fixed-speed compressors in a compressor rack leads to an extended working life of the refrigeration system
- Maximum rack refrigeration power is relatively high.

Please refer to the literature indicated [1] for further information on the Control Factor CF.

(6) The smallest possible inverter allowing safe compressor operation should be selected for reasons of cost-effectiveness.

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$$\text{Control Factor CF:} \quad \frac{\text{Variation of VsC refrigeration power}}{\text{Fixed-speed Compressor (FsC) step}}$$

VsC: **Variable-speed Compressor**
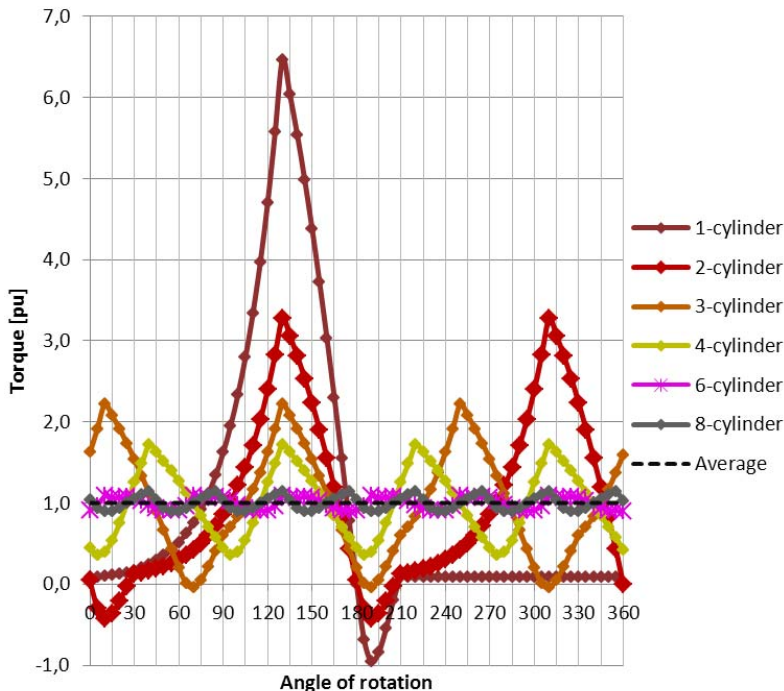FsC: **Fixed-speed Compressor**
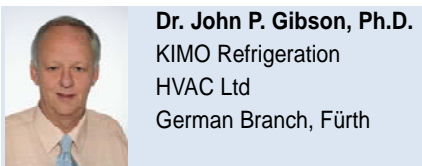
Fig. 2: Starting torque of reciprocating compressors with different numbers of cylinders

Motor-current based inverter selection

The Technical Information [2] describes a method for the safe selection of frequency inverters, based on the following data given:

- Maximum motor current, as stated in the compressor manufacturer's documentation.
- Factor considering the number of cylinders with reciprocating compressors
- Factors relevant for screw and scroll compressor units
- Use of conventional industrial inverters

Based on the above data given, the inverter starting current required can be calculated. Frequency inverters selected on the basis of this method will operate reliably and without any risk for the compressor. However, a disadvantage of this method is that in many cases the frequency inverter chosen is too large and therefore too expensive.

New method of frequency inverter selection

By means of the new selection software *FrigoPack*-select by KIMO RHVAC several new factors and criteria are considered in addition to dimensioning on the basis of motor-current alone:

(7) Compressor start scenario – establishing worst-case start-up conditions. A compressor start at a high ambient temperature after a long-term power-failure (>= 15 minutes) is considered as the most difficult starting condition. In accordance with the information provided in the software of most compressor manufacturers the following starting points will be used:

- Evaporating temperature: …10 °C (depending on the refrigerant used)
- Condensing temperature: corresponding to the ambient temperature, e.g. 43 °C in summer

(8) Consideration of refrigerant characteristics. Starting with R134a for

example requires less starting torque than starting with R404A.

(9) Consideration of compressor make and type. With reciprocating compressors the number of cylinders is particularly important (see Fig.2). The starting torque of a 2-cylinder compressor e.g. is twice as high as the average torque.

(10) Consideration of rack-assisted starting. With an intelligent control system such as Isesco from KIMO RHVAC, fixed-speed compressors are started first. As soon as suction pressure is close to the setpoint, the frequency-controlled compressors are activated.

(11) Calculating the starting current required.

(12) Selection of the smallest possible refrigeration inverter able to supply the starting current needed.

For manual selection, a consideration of all above factors described above would be too complicated. Detailed frequency inverter and compressor information stored in a data base accessed by a selection software is necessary.

For KIMO RHVAC this was the background for the development of the data-based online selection software "FrigoPack-select" for its refrigeration inverters, launched on Chillventa 2012. The software integrates a data base with information on 1.200 different compressors which is continually updated with new types. The software is available on www.frigokimo.com.

Software data input
The following data are required by "FrigoPack-select" to select a suitable refrigeration inverter:

- Compressor manufacturer: currently Bitzer, Bock, Dorin, DWM-Copeland, Frascold and Frigopol
- Refrigerant: currently R 404A / R 507, R 134a, R 22, R 407C, R 410A, R 717, R 744_SC/TC
- Compressor type: currently reciprocating, screw and scroll (semi-hermetic, hermetic or open)
- Compressor selection list including all relevant electrical and refrigeration data.
- Electrical supply voltage (400 V pre-selected)
- Motor connection: Star, delta, part-winding
- Starting torque factor: Taking into account starting conditions such as the maximum ambient temperature and/or rack-assisted starting

Example 1 for Software data output:
Bitzer compressor, two cylinders, R 404A, HT, IT, MT and LT

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COMPRESSOR DATA INPUT		
Manufacturer:	BITZER ▼	Refrigerant: R404A_R507 ▼
Type:	RS-2 Reciprocating, semi-hermetic, 2 cylinder ▼	
Compressor Chosen:	2CES-4Y ▼ Frame size: CE2	Displacement: 16,2
Preferred for VsC:		CC: 100%
Electrical Supply Voltage:	3AC 400	Elec. Booster[1]: 400
Motor connection[2]:	Star	Max. current: 10,0
Start Torque Factor (STF)[3]	1,00 ▼	

FrigoPack® SELECTION		FrigoPack®	Electrical input[4]	Electrical output[5]
FrigoPack-FEP	Classic Plus Line Refrigeration Inverters	FP 6.0FEP-EMC	3: 20 A	28: 5.5 kW / 12/35 A
FrigoPack-FUP	New Plus Line (2014) Refrigeration Inverters	FP 4.0FUP-EMC	1: 10 A	28: 5.5 kW / 12/35 A
FrigoPackE	Economy Line Refrigeration Inverters	FPE 5.5FMV-EMC	3: 20 A	28: 5.5 kW / 12/35 A
FrigoPack S:	Soft-start switches	FP 5.5SM2/T400		28: 5.5 kW / 12/35 A
FREQUENCY RANGE		Maximum:	Minimum:	Control factor[6]
Operating Temperatures:	HT1: +5/ 50° C	58 Hz	30 Hz	56%
	IT1: 0/ 45° C	64 Hz	27 Hz	75%
	MT1: -10/ 45° C	70 Hz	27 Hz	86%
	LT1: -35/ 40° C	70 Hz	30 Hz	80%

Software data output
After data entry and calculation, a list of selectable refrigeration inverters is presented:

- Inverters type FrigoPack FEP for medium and high level refrigeration control and complex refrigeration functionalities, as in chiller or heat pump systems
- Inverters type FrigoPackE economy line for standard control in commercial refrigeration
- Soft-start switches type FrigoPack S for soft starting of compressors with fixed frequencies.

Furthermore the FrigoPack-select software provides the following data:

- Suggested frequency range (fmax…fmin)
- Control factor CF for rack operation

- Suggested rating for electrical switchgear. Read more about this in the following.

Project-based selection of electrical switchgear
In many cases information on electrical switchgear is included in the inverter manufacturers' technical documentation. However, switches and cables are usually overdimensioned, as inverter operating data are not suitable for the selection of switches and cables in refrigeration applications.
Very often too much copper is used.

It is more economical to select electrical switchgear on the basis of the compressor's electrical operating data. The FrigoPack-select software offers suggestions for the following:

- Input fuses or circuit breakers
- Contactors
- Cable cross sections (with separate table)

FrigoPack® SELECTION APP

COMPRESSOR DATA INPUT

Manufacturer:	BOCK ▼	Refrigerant:	R134a ▼
Type:	RS-4 Reciprocating, semi-hermetic, 4 cylinder ▼		
Compressor Chosen:	HGX 6/1410-4 R134a ▼ Frame size: HG6	Displacement:	122
Preferred for VsC:		CC:	100/50
Electrical Supply Voltage:	3AC 400	Elec. Booster[1]:	400
Motor connection[2]:	Star	Max. current:	57,0
Start Torque Factor (STF)[3]	1,00 ▼		

Example 2 for Software data output:
Bock compressor, 4 cylinders, R 134a, HT, IT, MT

FrigoPack® SELECTION		FrigoPack®	Electrical input[4]	Electrical output[5]
FrigoPack-FEP	Classic Plus Line Refrigeration Inverters	FP 30FEP-EMC	9: 80 A	47: 30 kW / 65/90 A
FrigoPack-FUP	New Plus Line (2014) Refrigeration Inverters	-	14: 250 A	47: 30 kW / 65/90 A
FrigoPackE	Economy Line Refrigeration Inverters	FPE 30FEP-EMC	9: 80 A	47: 30 kW / 65/90 A
FrigoPack S:	Soft-start switches	FP 22SE3-27		47: 30 kW / 65/90 A
FREQUENCY RANGE		Maximum:	Minimum:	Control factor[6]
Operating Temperatures:	HT1: +5/ 50° C	70 Hz	25 Hz	90%
	IT1: 0/ 45° C	70 Hz	23 Hz	94%
	MT1: -10/ 45° C	70 Hz	23 Hz	94%
SPECIAL CONSIDERATIONS		Please refer to KIMO RHVAC		

Conclusions

With the software application "FrigoPack-select" a fast and exact selection of refrigeration inverters and electrical controls and equipment is made possible. The equipment suggested is often more economical than that chosen with conventional methods. With regard to energy efficiency FrigoPack-select calculates the important rating factor, "Control Factor CF".

The concepts presented are currently discussed within the ASERCOM work group "Frequency Inverters". A guide-book with "Recommendations for using frequency inverters with positive displacement refrigerant compressors" has been published by ASERCOM. Others will follow.

→ **www.frigokimo.com**