Frequency Inverters to save energy

ASERCOM – EPEE Symposium

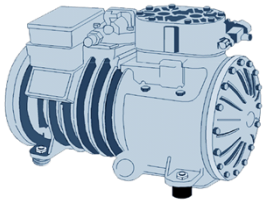
John P. Gibson
ASERCOM WG Inverter

Nuremberg, 10.10.2016

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Participating in the *ASERCOM* Work Group Inverter

- Semi-hermetic Refrigerant Compressors:
  - BITZER (D)
  - DORIN (I)
  - EMERSON Climate Technologies (B + CZ)
  - FRASCOLD (I)
  - GEA-BOCK (D)
  - INGERSOLL-RAND (CZ)



- Hermetic Refrigerant Compressors
  - BITZER (D)
  - DANFOSS (DK)
  - EMERSON Climate Technologies (CZ)
  - TECUMSEH (F)

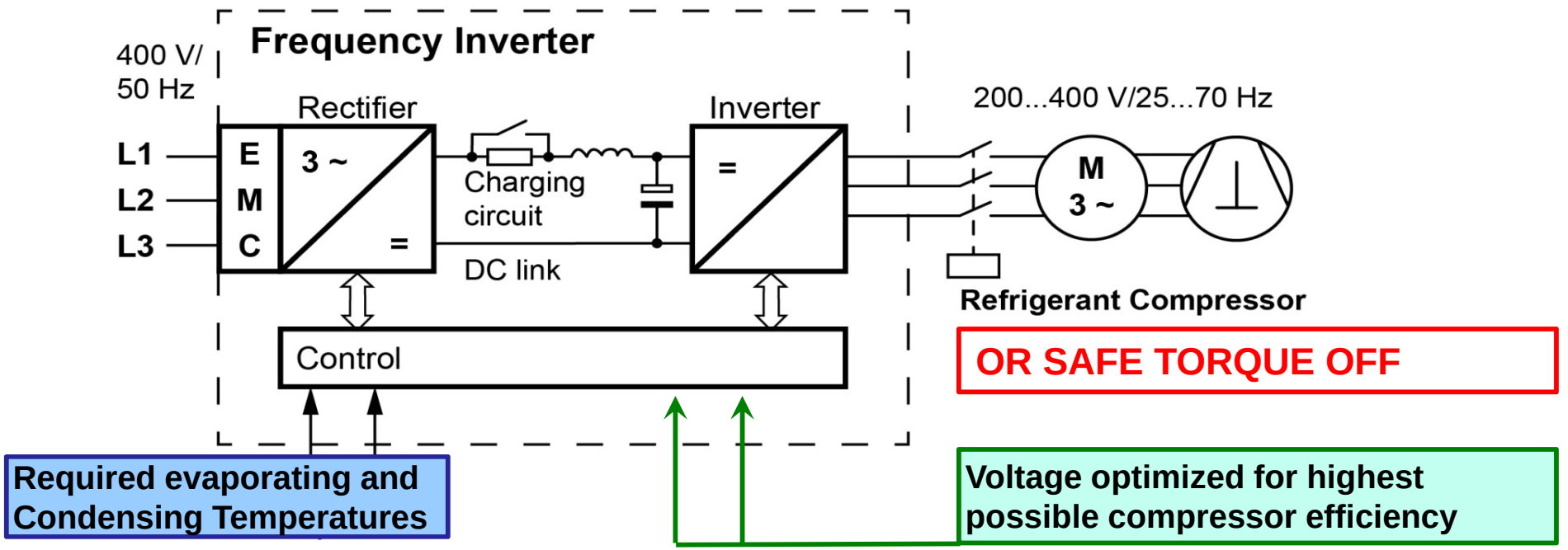
- Inverters for Refrigeration Technology
  - BITZER (D)
  - DANFOSS (DK)
  - KIMO RHVAC (D)
  - LODAM (DK)

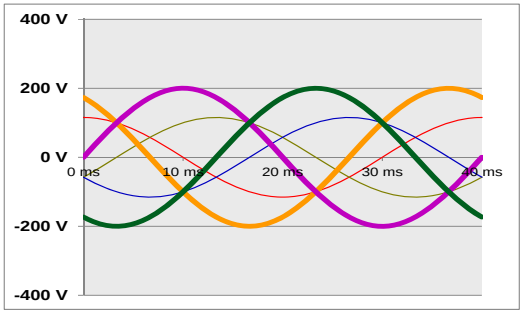
- Compressor Monitoring
  - KRIWAN (D)

A Team Effort

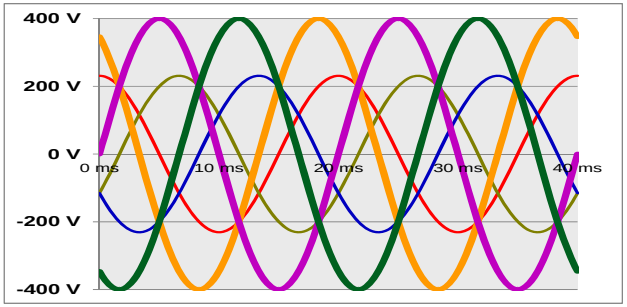
ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

What is a Refrigeration Inverter ?

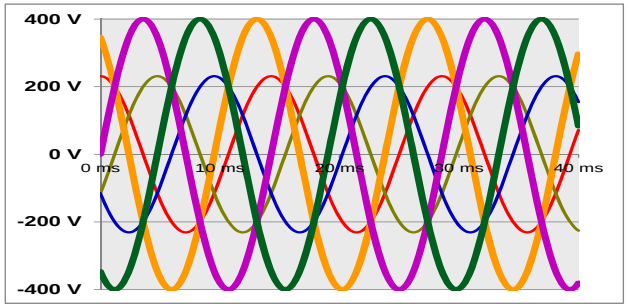




f: 25 Hz, 200 V
50 % capacity



f: 50 Hz, 400 V
100 % capacity



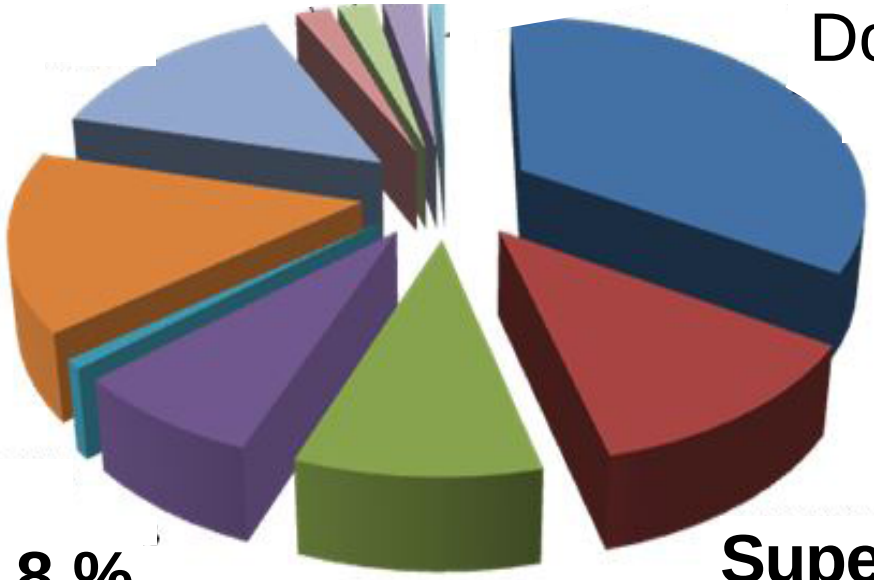
f: 70 Hz, 400 V
140 % capacity

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Some Energy Figures

- Electrical energy used for Refrigeration and Air Conditioning: 14% of total electrical energy consumption
- **In Refrigeration and Air Conditioning**

Industrial: 14 %



Domestic

Aircon: 15 %

Retail: 8 %

Food Industry: 9 %

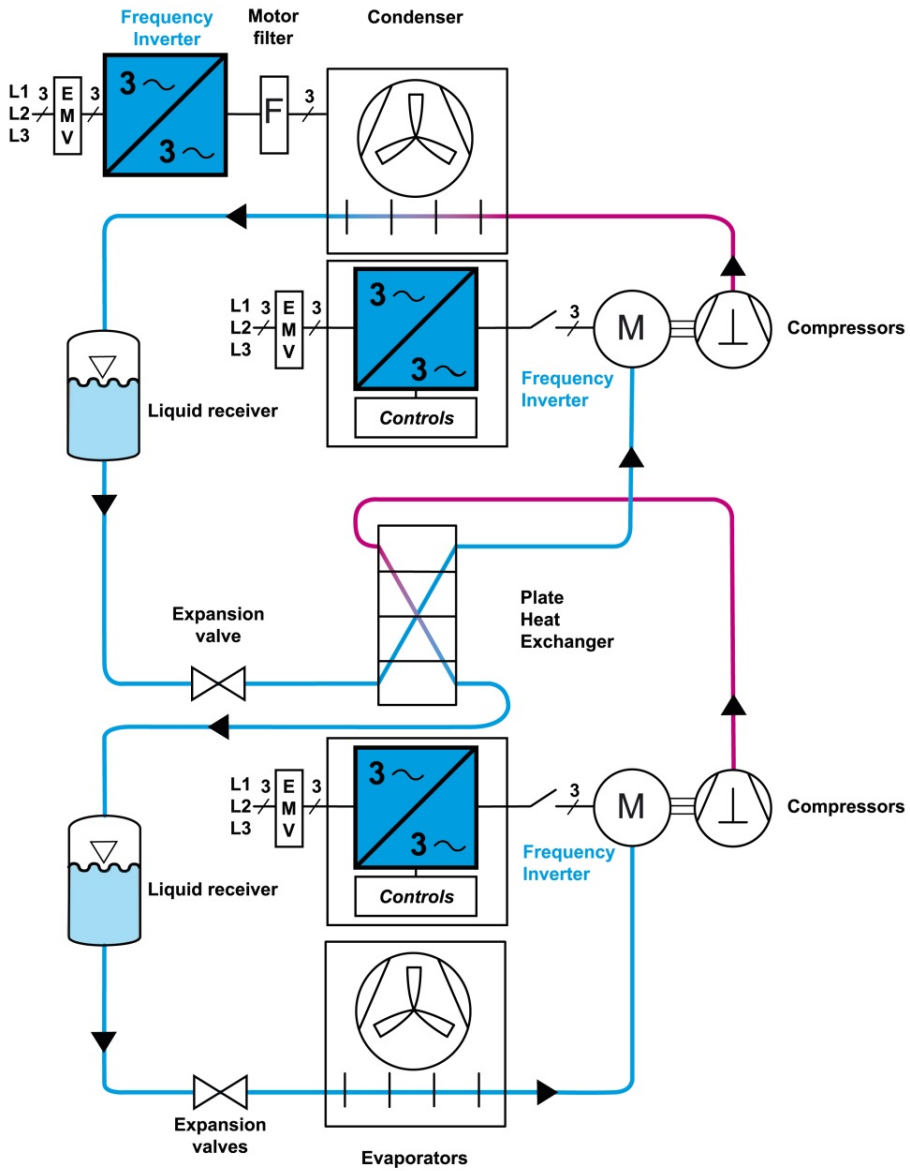
Supermarkets: 12 %

Data from the German Federal Environmental Agency

Relevant for Frequency Inverters: 58 %

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Refrigeration Inverters for Indirect Cooling with a flammable refrigerant



Cascade cooling of hop pellets for beer:

LT (-40 °C): R744 (CO_2)

MT: R290 (Propane)

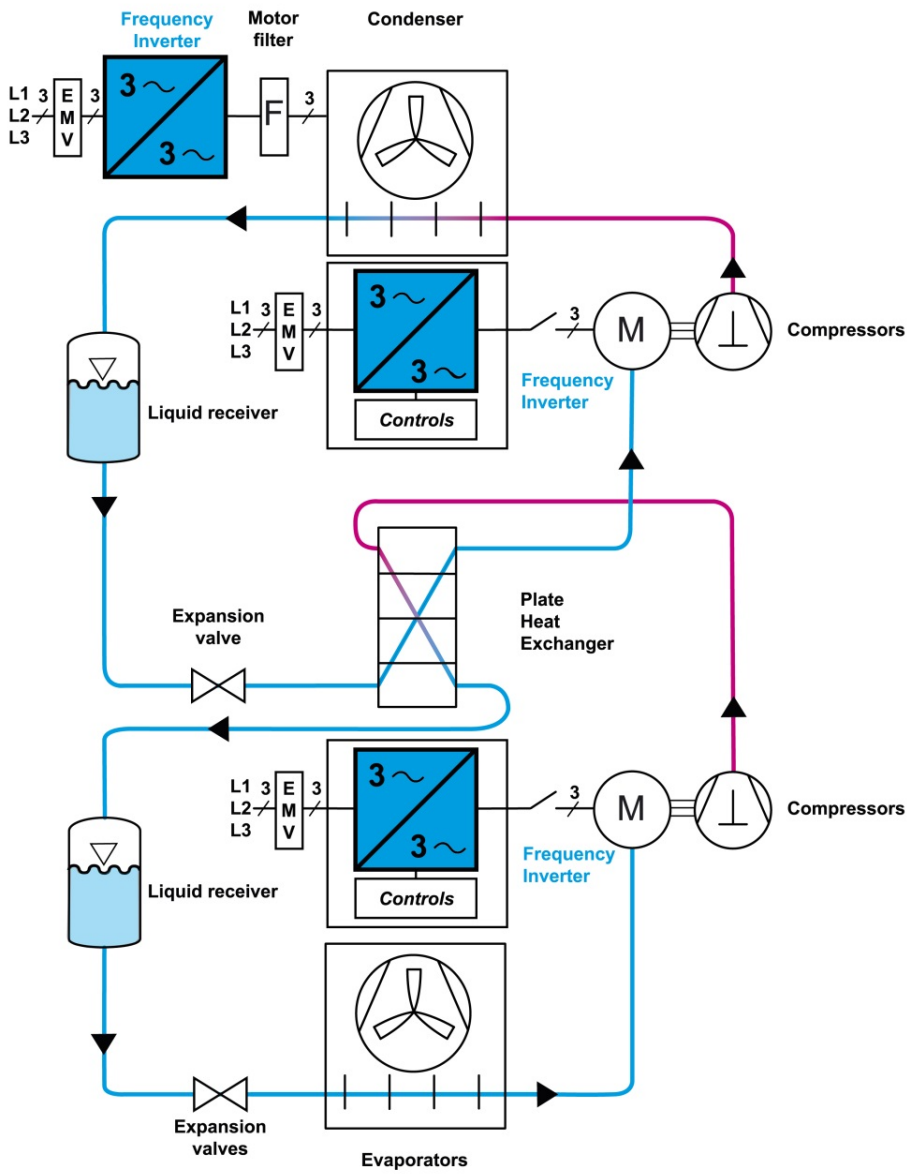
Heat recovery

Modernisation of existing plant:

50 % Energy saving measured 2015 / 2014

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Refrigeration Inverters for high-efficiency Cascade Systems



Large new Bakery:
LT: R744 (CO_2), MT: R1234ze
4x Energy Saving Refrigeration Inverters

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

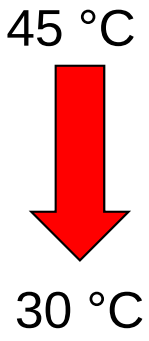
Improving Compressor Operation and Control

- Decreasing Condensing temperature pc:
  - One K (°C) decrease ➔ (achievable, depends on annual temperature profile)

1…2 % energy saving with Medium Temperature (-10 °C)

0.5 …1 % energy saving with Low Temperature (-35 °C)

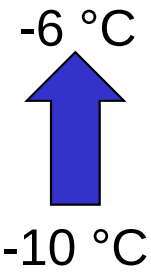
(Source: Carbon Trust, UK)



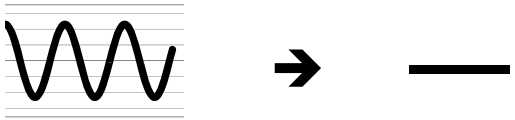
- Increasing evaporation temperature pe:
  - One K (°C) increase ➔ (achievable, depends on display-case design and operating conditions)

2…4 % energy saving

(source: KÜBA Heat Exchangers)



- Stable operating point pe:
  - Inverter-Control provides for stable operation of expansion valve➔ (achievable, depends on design)



10 … 20 % energy

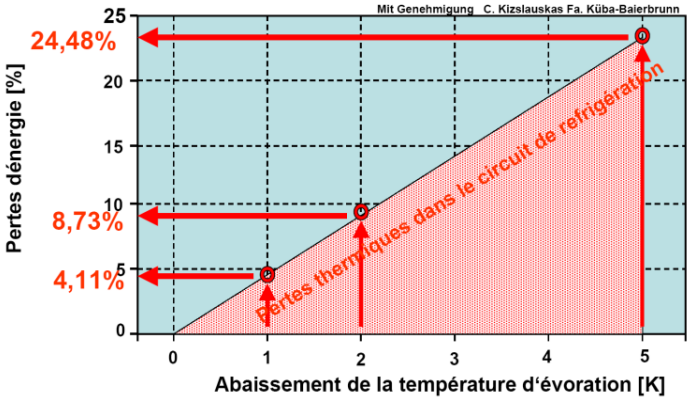
(source KIMO RHVACC)

Actual energy saving figures under Work Group review

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Experience with Inverter energy saving

- Thermodynamic targets:
  - Condensing temperature ↓
  - Evaporating temperature ↑



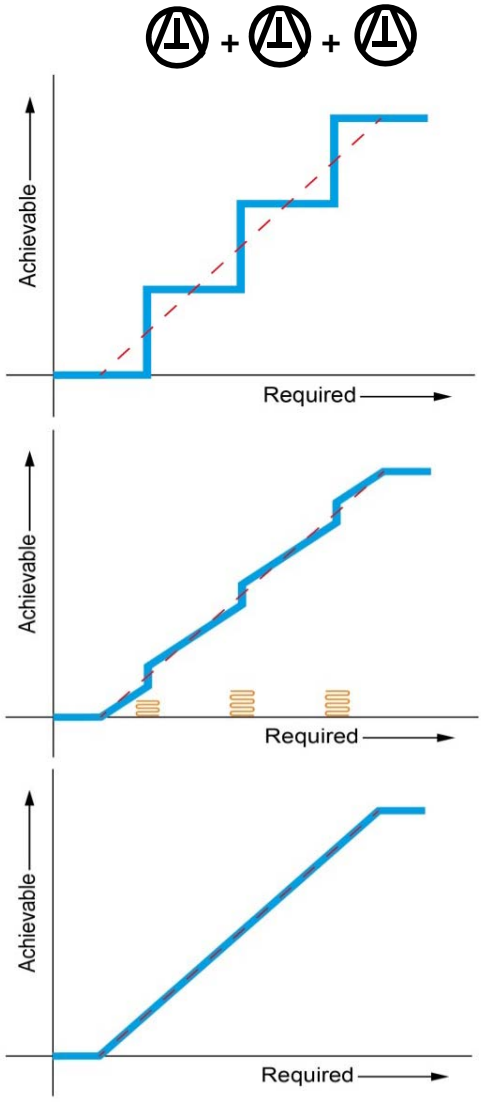
Publication from KUBA evaporators:

- Energy saving with inverter compressor control
  (Experience assuming full advanced floating and optimized control of evaporating and condensing temperatures):
  - 1x compressor: 30 … 40 %
  - 2x compressor rack: 20 … 25 %
  - 3x compressor rack: 17 … 22 %
  - 4x compressor rack: 15 … 20 %, (At low capacity: 20 … 25 %)

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

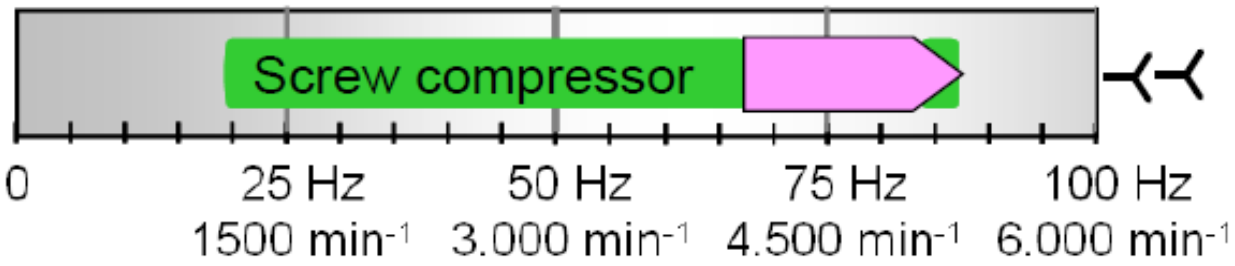
Achieving a stable compressor operating point with multi-compressor racks

- **Step control without an inverter:** ☹
  - Frequent STARTING and STOPPING (**Too much** or too little capacity)
  - Large fluctuations in Evaporating Temperature: Little Energy Saving
- **Poor-design inverter control:** 😐
  - Unnecessary STARTING and STOPPING (instability at certain operating points)
  - Fluctuations in Evaporating Temperature: Some Energy Saving
- **Good-design inverter control:** ☺
  - Minimum STARTING and STOPPING (stable operation due to wide range of speed): Optimum Energy Saving and Cooling Quality

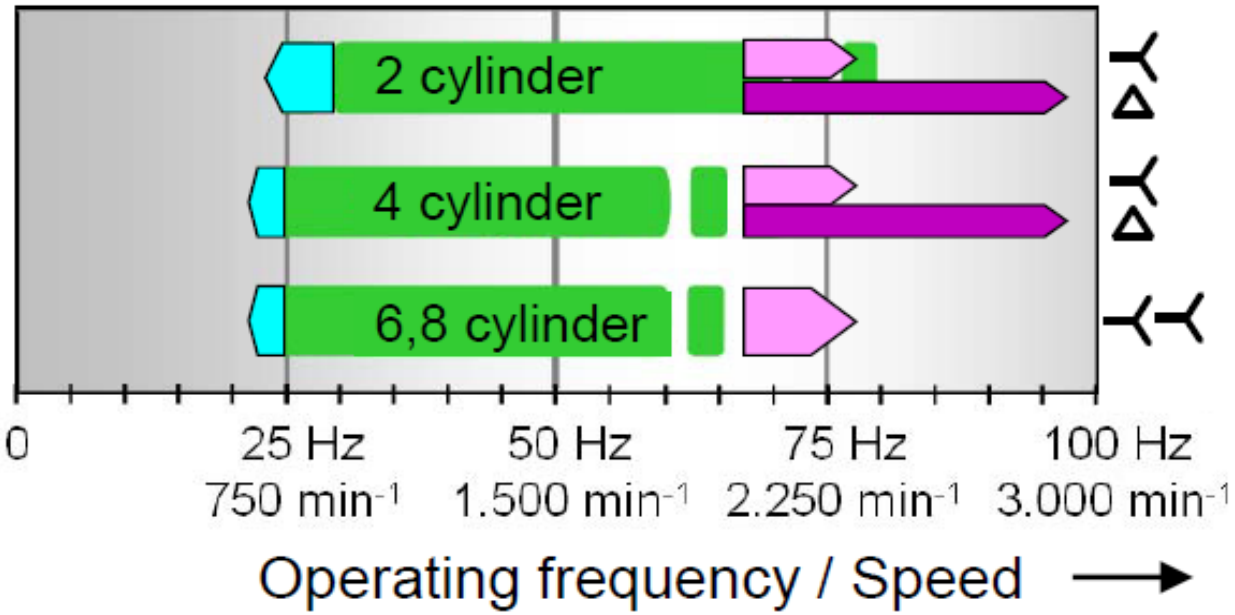


ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Importance of achieving a wide range of permissible operating frequency



f_{max} limit:
Automatically self-adjusting
(Intelligent Sliding Control)

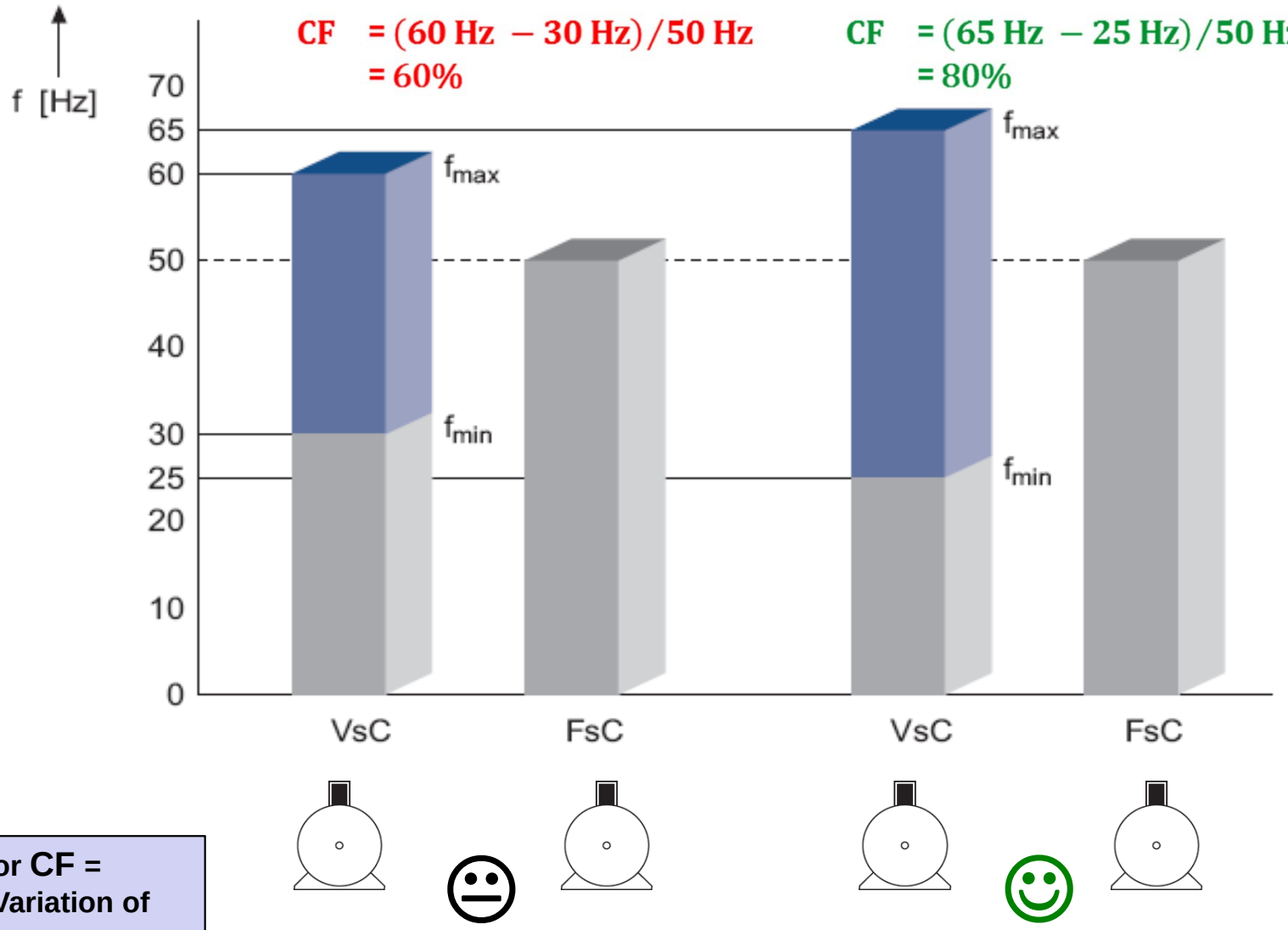


f_{min} limit:
Automatically self-adjusting
(Intelligent Sliding Control)

Intelligent Sliding Control:
Based on:
Refrigerant,
p_0, p_c, t_s, t_d, M_{mot}

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Benefit of a wide range of compressor frequency: Example with two-cylinder compressors



Example for Identical-sized 2-cylinder compressors

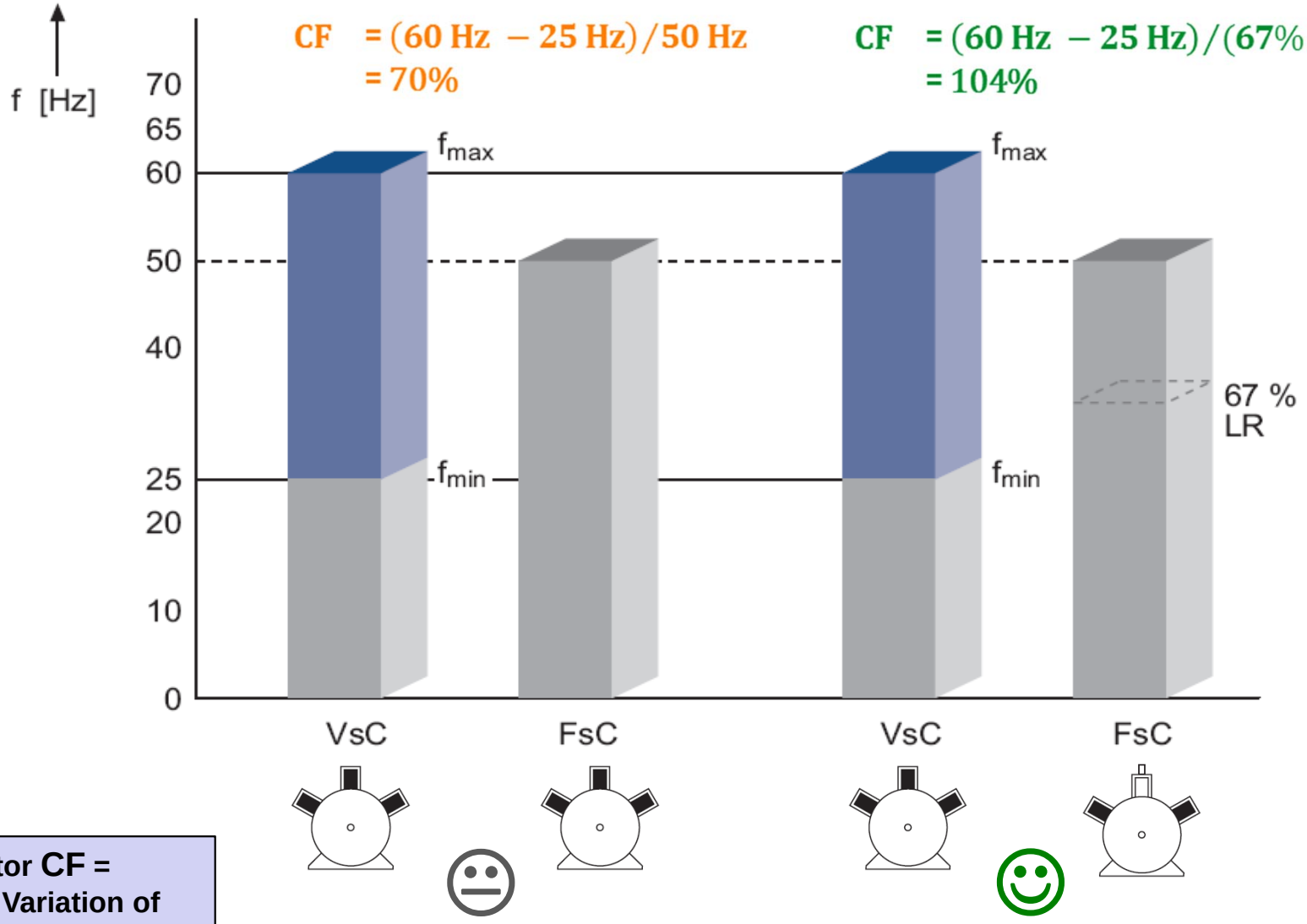
Control Factor CF =

$$\frac{\text{Capacity Variation of Inverter compressor}}{\text{Capacity of next step}}$$

The higher the Control Factor the better the Energy Saving

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Benefit of a wide range of compressor frequency: Example with six-cylinder compressors



Example for identical-sized 6-cylinder compressors

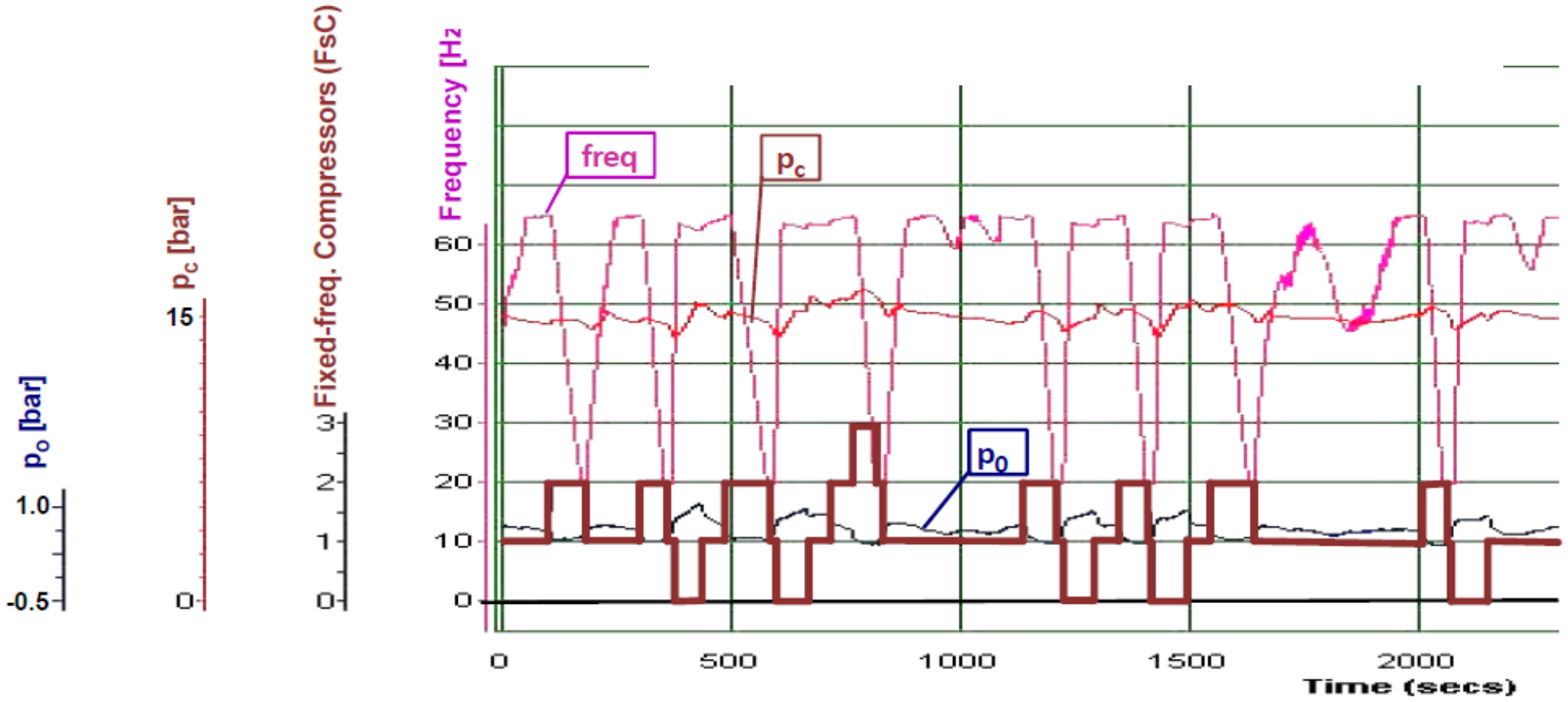
Control Factor CF =

$$\frac{\text{Capacity Variation of Inverter compressor}}{\text{Capacity of next step}}$$

The higher the Control Factor the better the Energy Saving

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Example of a real supermarket installation with a low Control Factor



Installation:
Supermarket with
4 compressor rack

Control Factor:

Originally:	25 ... 60 Hz:	47%
Extended Frequency Range:	20 ... 65 Hz:	60 %

Shown here

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

How can *ASERCOM* assist with using inverters in refrigeration ?

- Provide design software for compressor manufacturers

  Mathematical basis for calculation of the electrical performance limits with frequency inverter operation:

  - ➔ Maximum and minimum frequency at each refrigerant and operating point

  - ➔ Performance projection, in particular the

    Coefficient **O**f **P**erformance **COP**:

    $$\textbf{COP} = \frac{\text{Refrigeration capacity}}{\text{Electrical consumption}}$$

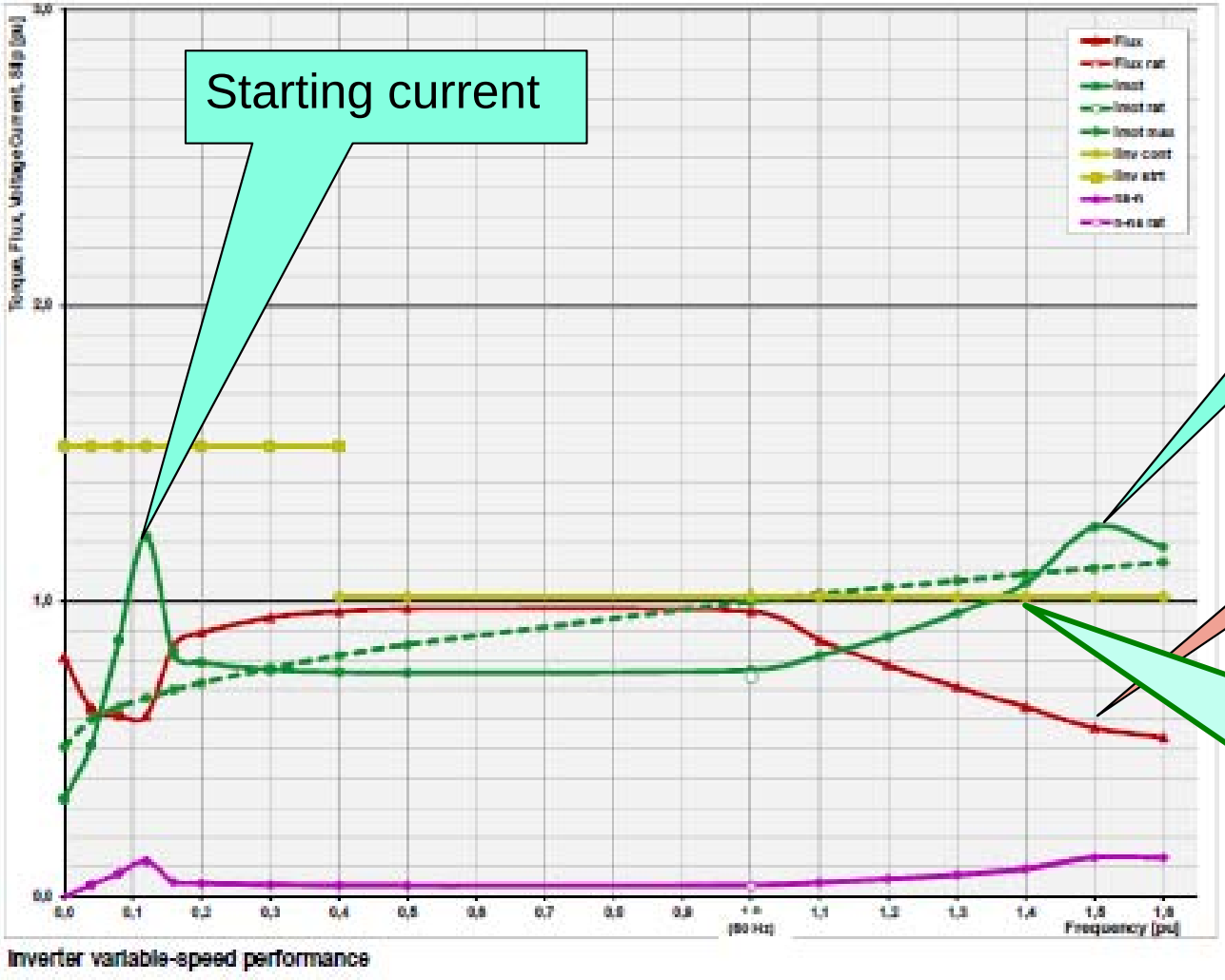
    at all load conditions.

  - ➔ **C**ontrol **F**actor

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

How can *ASERCOM* assist with using inverters in refrigeration ?

- Calculation Tool for compressor manufacturers



ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

How can *ASERCOM* assist with using inverters in refrigeration ?

- Issue Design Guides for the Refrigeration Industry:

  - On the general use of Inverter with Refrigerant Compressors (2010) (published as an ***ASERCOM*** Guide Book on **www.asercom.org**)

  - On the optimum design of Compressor Racks for high reliability and optimum Energy Saving (to be published soon as an ***ASERCOM*** Guide Book)

  - Others on electrical and Electromagnetic Compatibility (**EMC**) issues to follow.

NEW:
Almost ready

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Using inverters to improve refrigeration cooling quality

- **Constant evaporation temperature:**
  - Reduced temperature variations at the cooling outlets
  - Higher and Constant Humidity
  - Reduced weight loss by dehumidification

- **Improved evaporator Operation:**
  - Improved function of the Expansion Valves:
    - Higher evaporator efficiency by optimum filling
  - Less icing on the evaporators
  - Longer intervals before each defrost :
    - Reduced energy loss during defrosting

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS

Inverters to save energy: Summary

- **Energy saving with Inverters for:**
  - Compressor racks
  - Fans on condenser
  - Circulation pumps for secondary cooling

- **Improved Cooling quality:**
  - By <u>good System Design</u> (***ASERCOM*** explains how)

- **Extended Activities in 2016:**
  - Energy Management and Internet Security

- ***ASERCOM*** **Work Group inverter:**
  - 7x European Compressor manufacturers
  - 4x European Inverter manufacturers
  - 1x European Protection Equipment manufacturer

…

…

Providing Advice and Guide Books for the Refrigeration Industry

ASERCOM
ASSOCIATION OF EUROPEAN REFRIGERATION COMPONENT MANUFACTURERS