
VACON
DRIVEN BY DRIVES
Vacon Baltic Days
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Tallinn, Estonia
Vacon Technology
Yrjö Karvonen
Technical Account Manager

Frequency converter

Why to use

Energy saving

Easy to control (mA, V, digital I/O, Fieldbusses)

Better process quality

More volyme in production

No stress for supply network when starting motor

Limits mechanical stress for machines

Applications

Pums, fans

Conveyors

Compressors

Cranes, lifts

Extruders, mixer

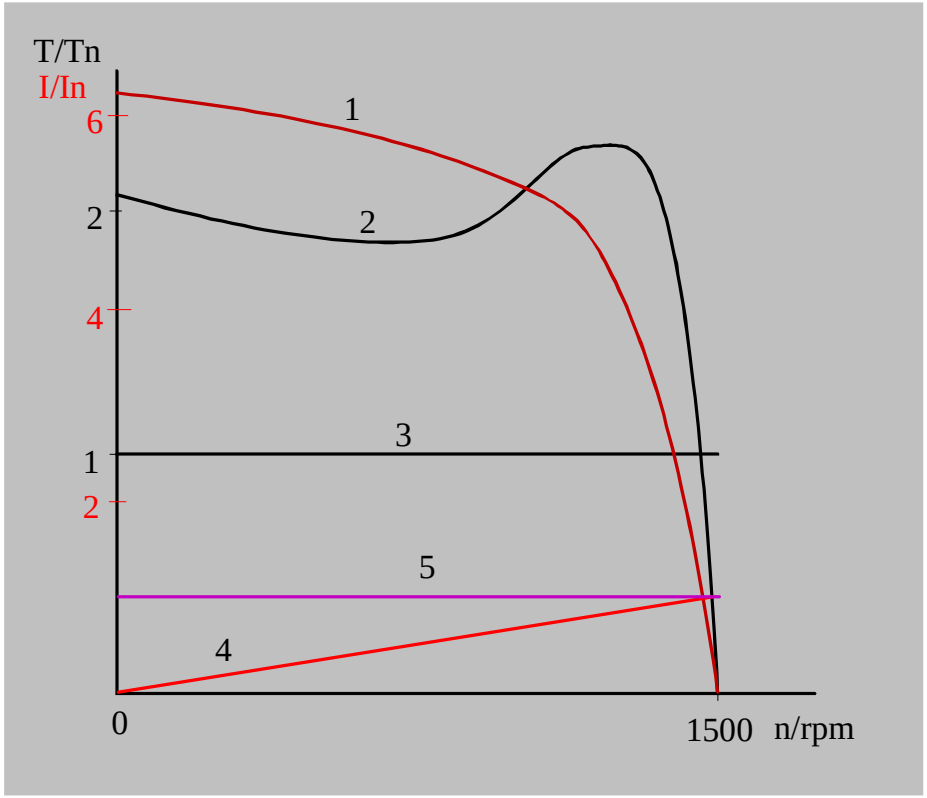
Paper machines etc.

Frequency converters

Use of frequency converters started to be more and more common after 1980 thanks to to new semiconductor technology which made possible to make new speed regulation system the industry was waiting for i.e at the same time:

- stepless
- easy to control
- almost maintenance free

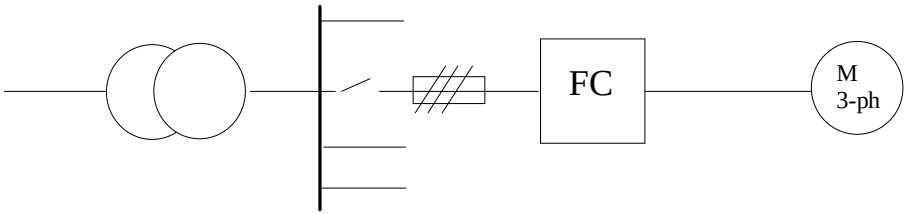
Starting current and torque



Torque <0.5*Torque of DOL

Supply start current <1/6*Current DOL

Supply voltage drop <1/6*drop DOL



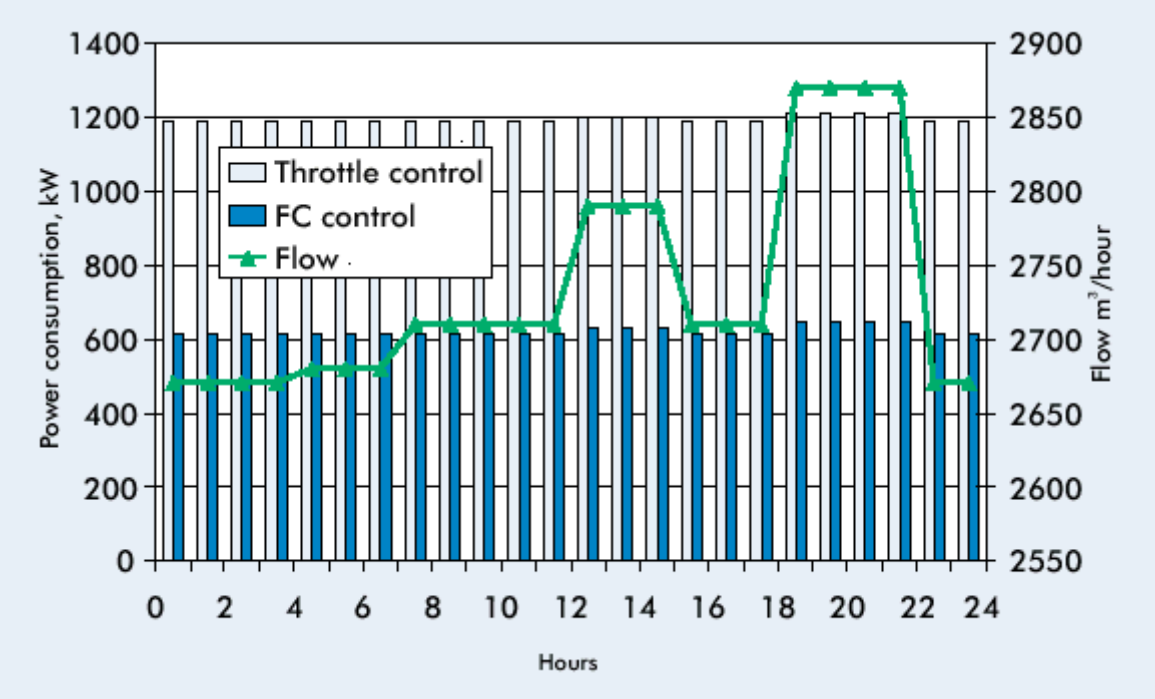
1. Supply starting current DOL
2. Starting torque DOL
3. Starting motor torque VSD

(Depends on set current limit and ramp up time)

4. Supply starting current VSD
5. Starting motor current VSD

Energy saving

When changing old systems to frequency converter regulated system, it is possible to get even under one year pay back times.

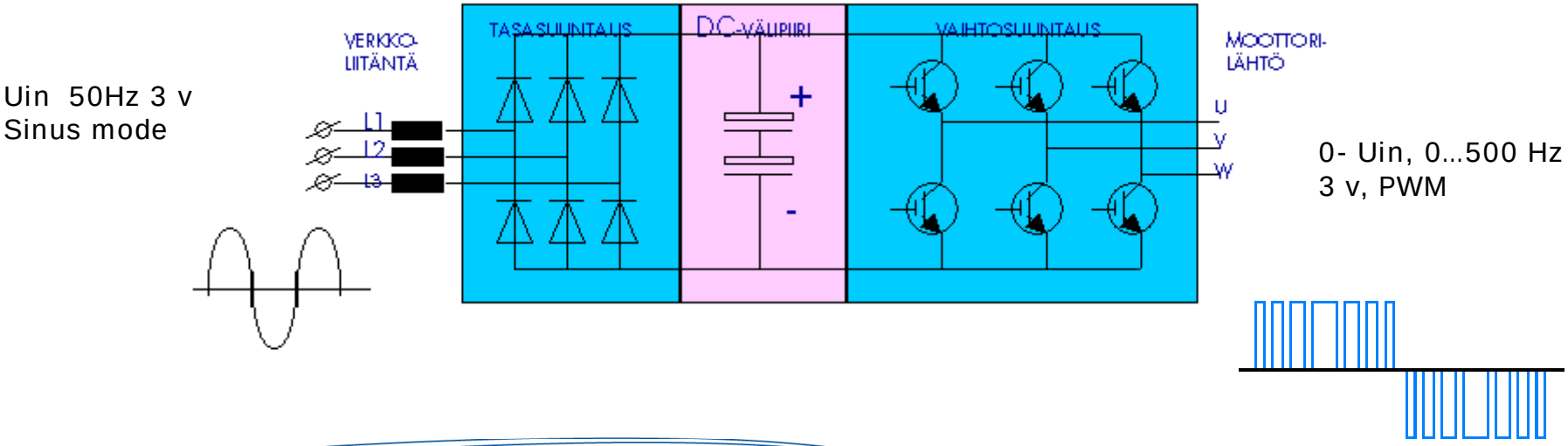


Pulse width modulation (PWM) frequency converter

Control I/O

Monitor

Motor control



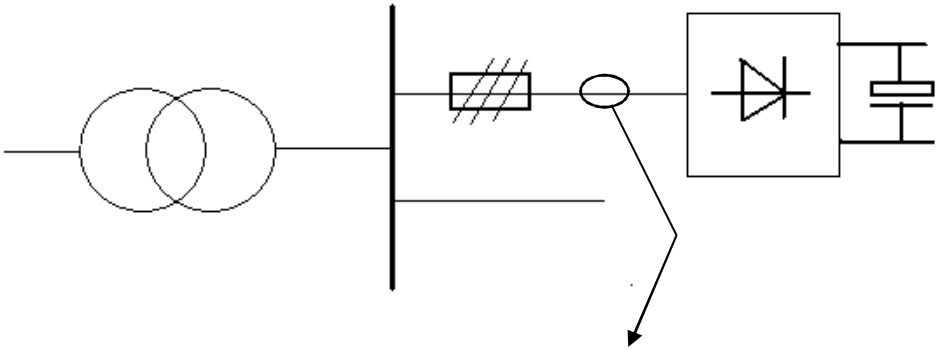
Uin 50Hz 3 v
Sinus mode

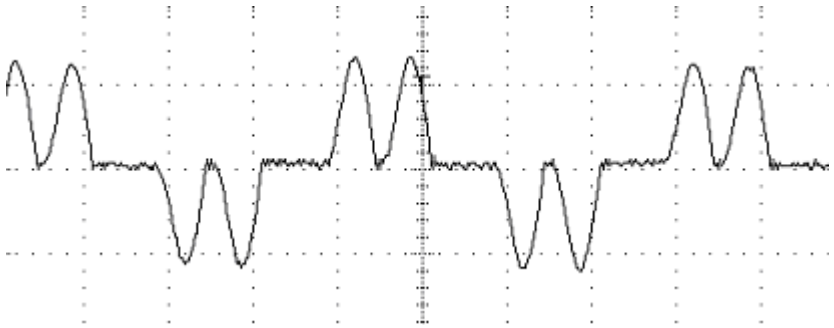
0- Uin, 0...500 Hz
3 v, PWM

Supply of frequency converter

Standard freq. converters have 6-pulse rectifier

- cos ω > 0.98 ➔ No need for copmpensation batteries (Note. Not allowed to connect compensation capacitors to VSD output)
- Supply network power proportional to shaft power P = ϖ*T
- Supply current has harmonics of order n*p(+/- 1), p=pulse number of rectifier. Orders of harmonic components of 6-pulse rectifier are 5th,7th,11th,13th ... = (250Hz ,350Hz ...)



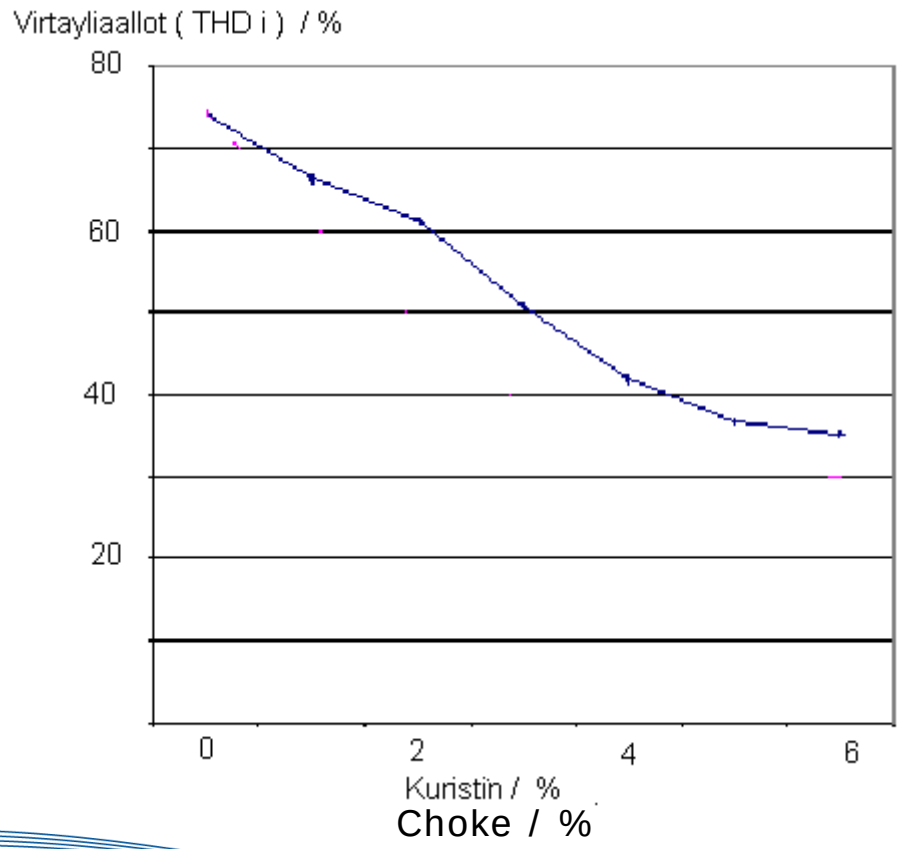


Typical input current waveform of 6-pulse rectifier.

Supply of frequency converter / harmonics

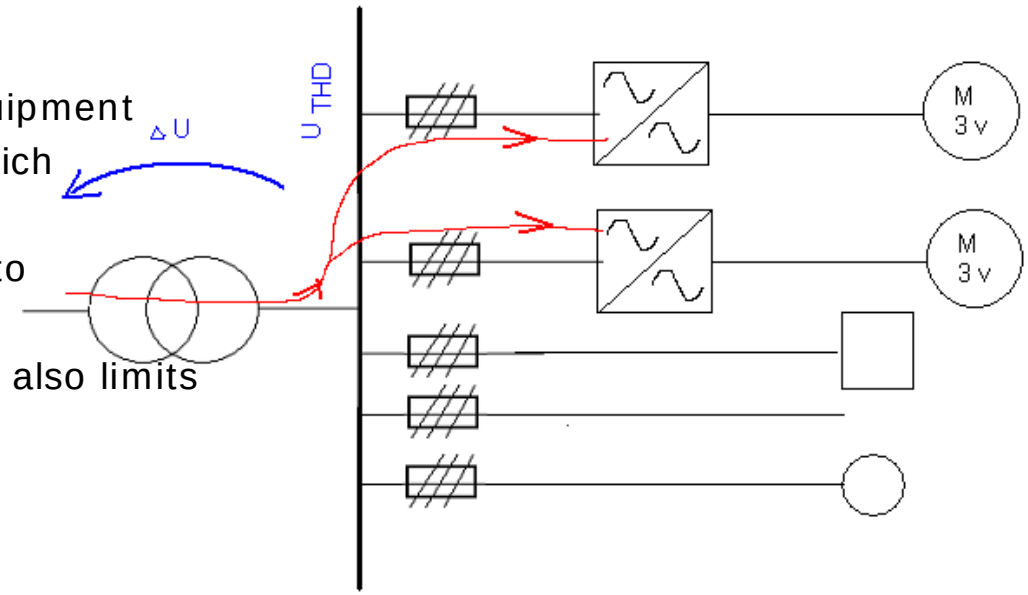
Amplitude of harmonic currents is strongly depending on whether fc has provided with choke or not. Choke can be whether in AC or DC circuit.

Total current distortion/ %



Supply of frequency converter / harmonics

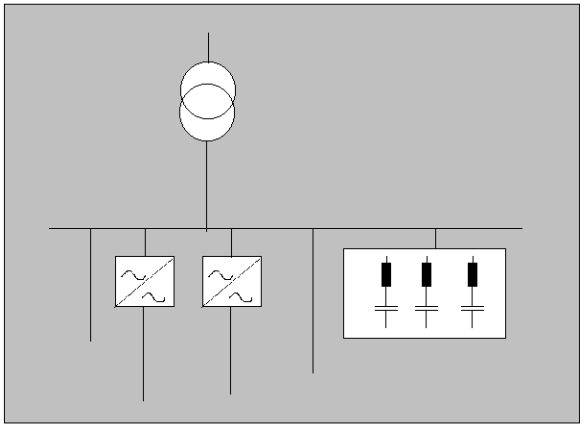
Harmonic current of individual devices is not most important but the influence of total harmonic current content generated by all equipment connected to network (SUM In (n=2....) which is then generating voltage distortion .
Total voltage distortion (THD) is then meter to evaluate the condition of network.
Standards take into account both THD and set also limits for individual voltage harmonics components.



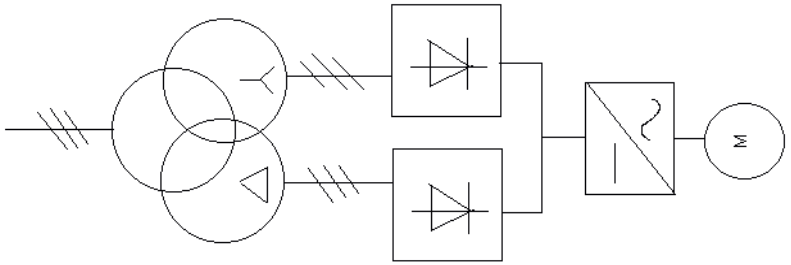
High voltage distortion causes:

- Extra load for cables and transformers
- Extra load for compensation capacitors
- Can cause malfunctions or extra losses on units connected to distorted network

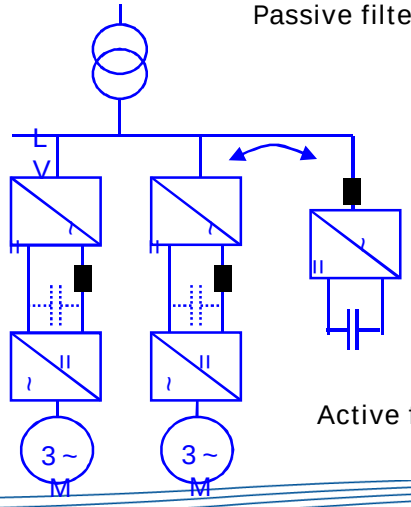
Supply of frequency converter / harmonics How to decrease



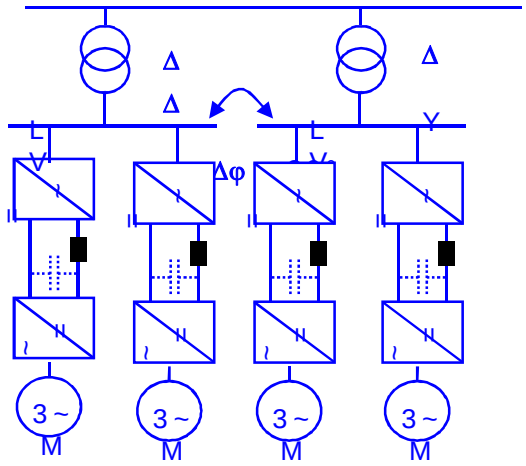
Passive filter



12 - or 18 – pulse rectifier



Active filter



Dividing the loads after different vector groups

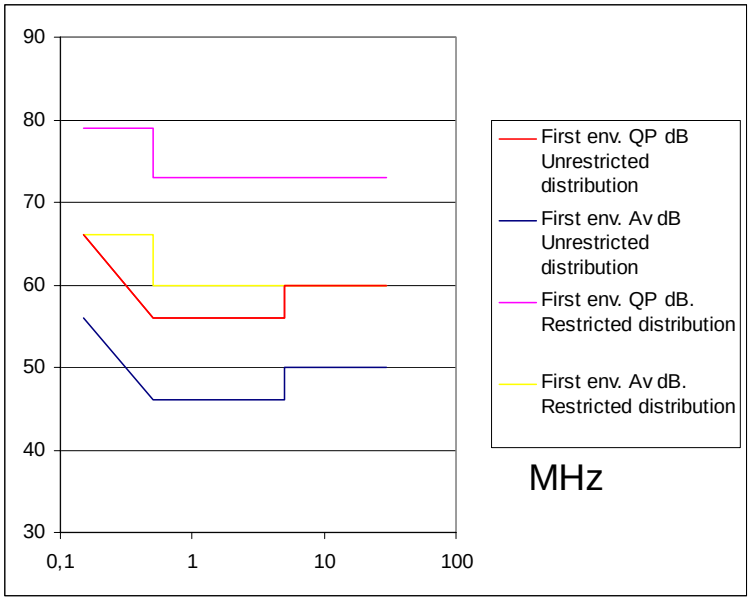
Frequency converter / hf-emission

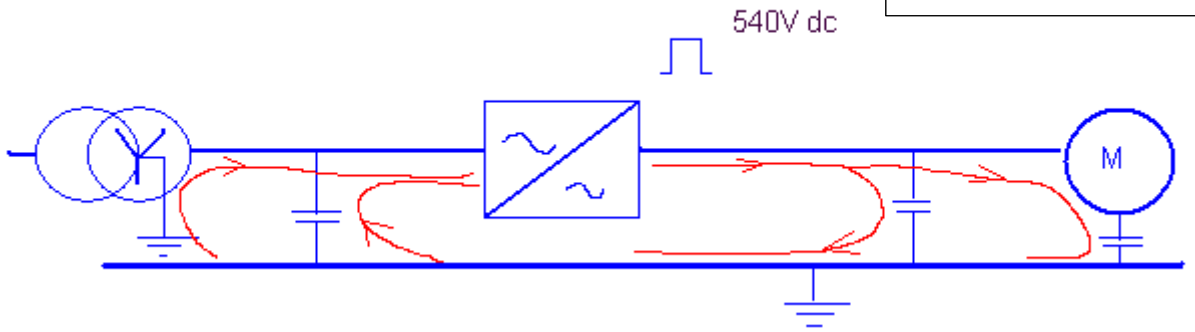
Output voltage is pwm-pulses.

Amplitude of each pulses same as DC-bus voltage. Pulses have fast rising/falling edges.

Each edges are charging and discharging system capacitancies → leakage currents.

Pulse edges are main source of hf-interferences.





Frequency converter / hf-emission

EMC standard concerning frequency converters

(EMC = Electromagnetic compatibility)

EN 61800 –3 + Amendment A11 (Adjustable speed electrical power drive systems. Part 3: EMC product standard including specific test methods.)

Standard defines limits/tests for immunity and emission .

There are 2 separate classes for environment:

1) First environment = Public network

2) Second environment = own distribution transformer (industrial network) = C3 = Class 3

First environment is having 2 separate sub categories:

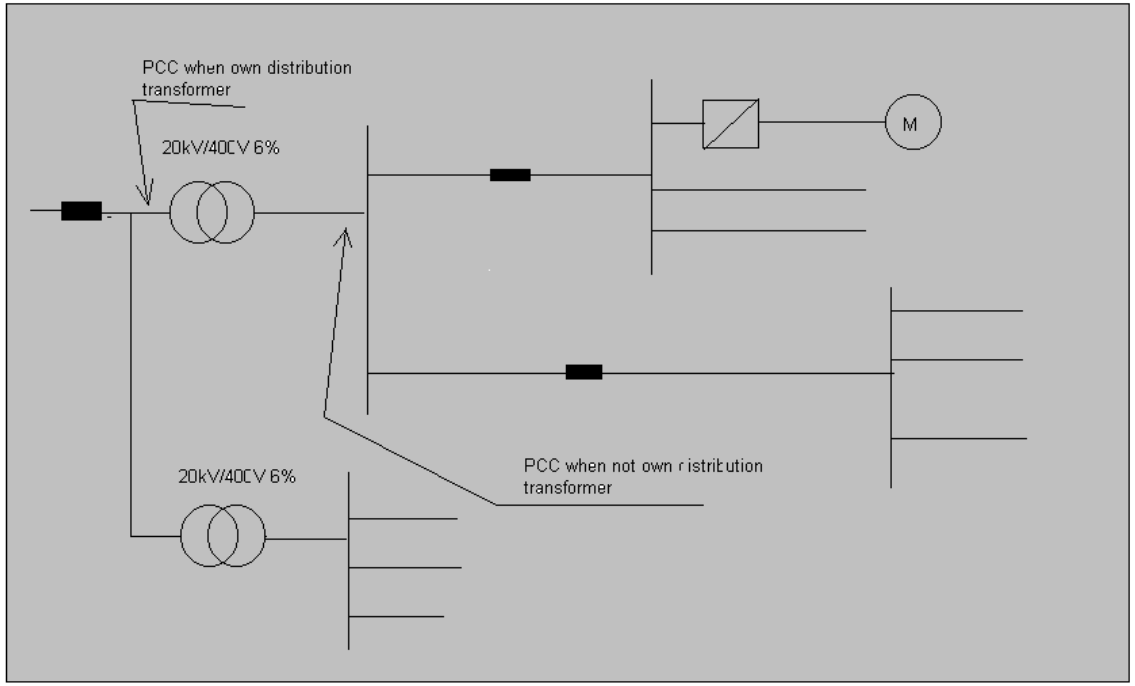
1) Unrestricted distribution = C1 = Class 1

2) Restricted distribution = C2 = Class 2

Frequency converter / hf-emission

Net owner has his own ” responsibility and freedom ”.

PCC (Point of common coupling).



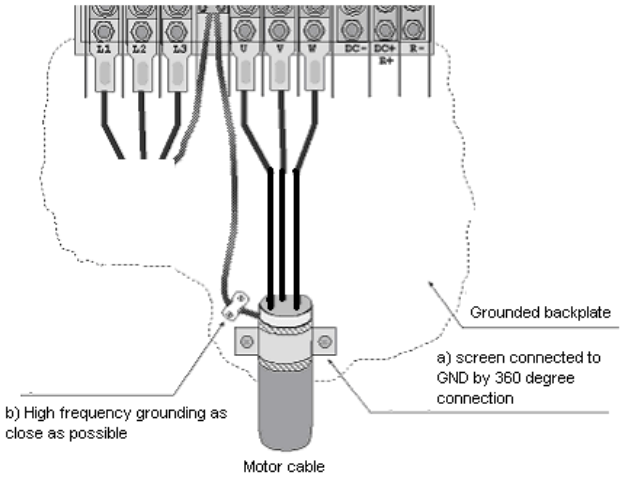
Standard makes no requirements:

- When IT- network
- When rated current over 400 A
- When voltage over 1000 V
- When filtering makes some other major problems

Frequency converter / hf-emission

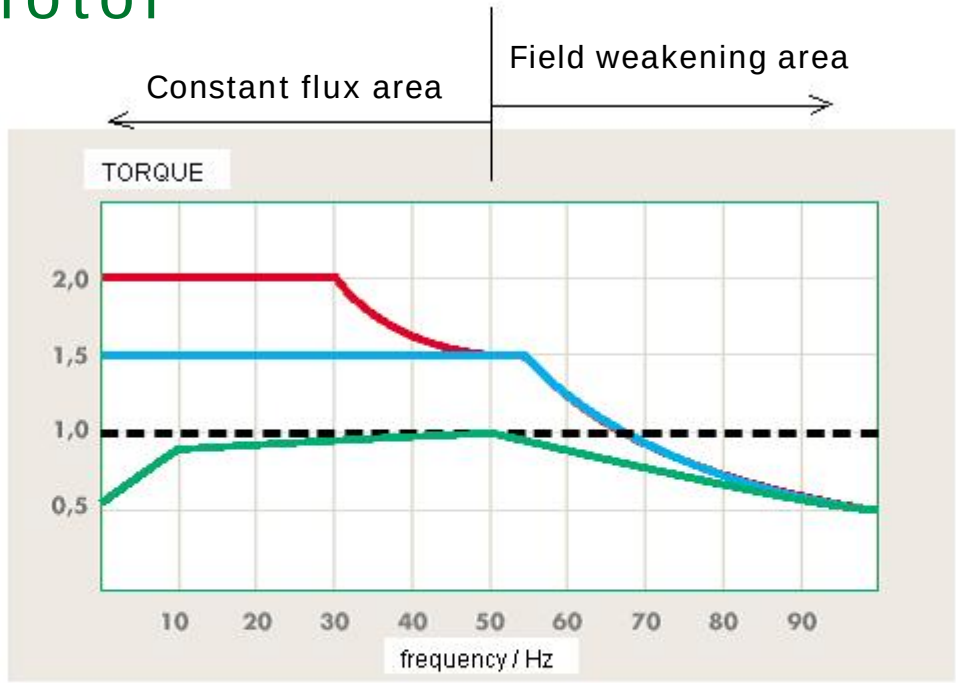
To prevent emc-problems

- Select correct type of VSD; Vacon has different inbuilt filters available .External filters available as well.
- Select correct power cable types. Best is to use special cable types which have hf-screen. For example MCCMK. MCMK is standard under ground cable and screen of it is not made for hf-protection. Motor cable is the major source of interference.
- Interferences produced by VSD are having high frequencies. That's why earthing of cable screens should be done in both ends of cable This concerns both power cables and control cables.
- 360 degree earthing is best. If not easy to make in practise, make hf-earhing so close the cable jacket stripping point as possible (within 0...3 cm)
- Keep motor cables separate from other cables.



Frequency converter/ motor

- FC makes possible to regulate standard squirrel cage motor stepless within wide speed area
- Can be used also with slip ring motors and permanents magnet motors.



Frequency converter/ motor

• Constant flux area

- Motor internal flux can be kept constant by increasing U as function of f (U/f=constant)

- When constant flux, T is proportional to effective current.

- At very low frequencies U/f-curve has to be lifted in order to keep constant flux (IR-compensation)

- Continous loadability of motor goes down at low frequencies due lower speed of motor shaft cooling fan.

• Field weakening area

- Motor flux goes down due U/f goes down.

- Motor max. torque goes down $(fn/f)^2$

- Motor continous torque goes down (fn/f) (constant current)

- Life time of bearings is shorter

Frequency converter/ motor

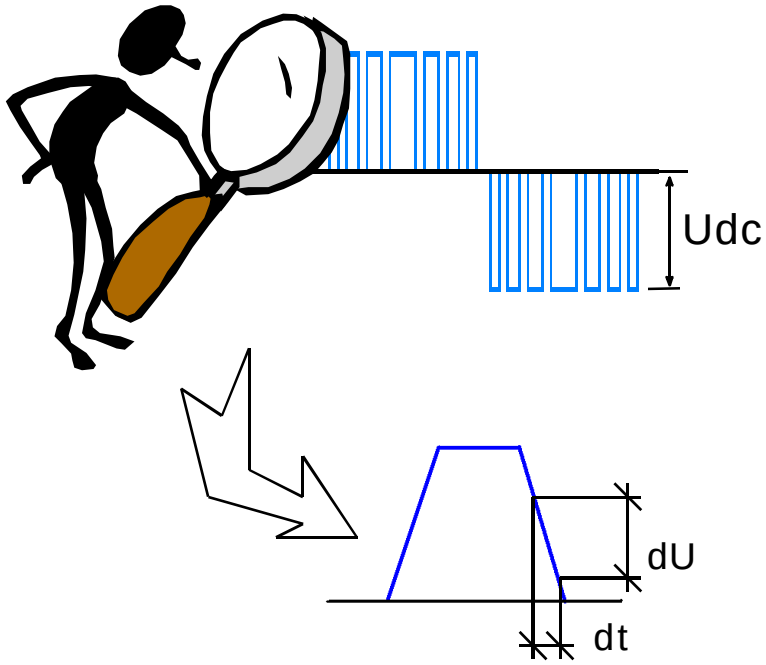
- Motor protection

-FC calculates motor thermal image as a function of set motor datas, actual motor current and speed.

-Ultra fast short circuit protection (< 10 us) , when short circuit on motor cable or inside motor.

Frequency converter/ motor/ motor insulation

Edges of PWM pulses make extra stress for motor insulation.



Typical switching times for different components

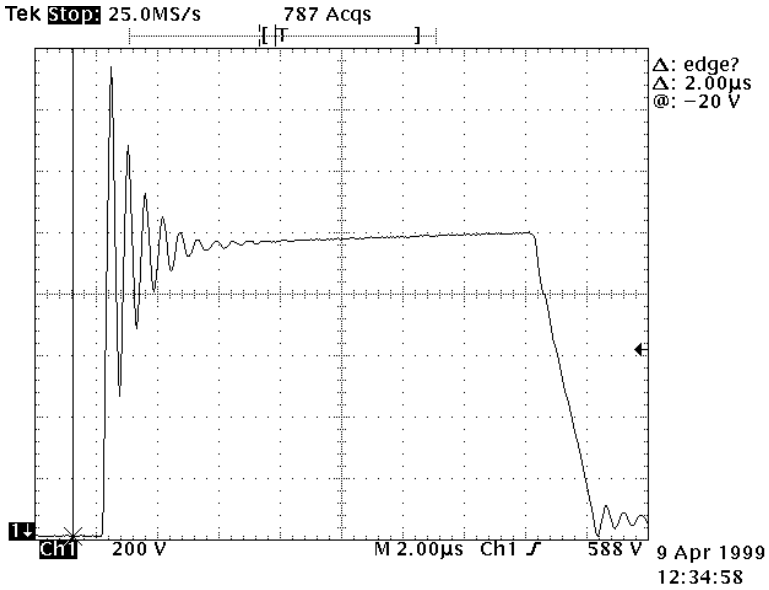
SCR	4.0 us
GTO	1.0 us
GTR	0.8 us
IGBT	0.1-0.2 us

dU/dt = 5...10 kV/us IGBT

High du/dt increases risk of partial discharges inside insulation.

Frequency converter/ motor/ motor insulation

- Edges of pulses are causing reflections at motor terminals which can in worst case double the voltage stress for a short moment (us).
- The extra stress is depending on du/dt, motor cable length and impedancies of cable and motor.
- With fc using IGBT transistors the max reflection can take place already under 10 m long motor cable.



Frequency converter/ motor/ motor insulation

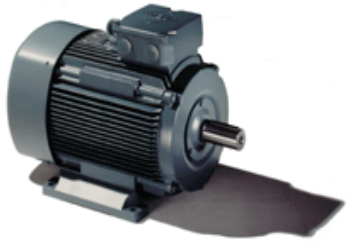
Motor suitability to frequency converter use has to be checked from motor supplier !!!

Some common practise with few big motor suppliers:

400 V net: Standard motor series can be used

500 V net: On the limit. Some of motor suppliers promise to use standard motor.

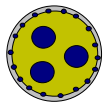
690 V net: Typically combination is motor with reinforced insulation + du/dt filter after fc.



Frequency converter/ motor/ bearings

Increased risk of bearing currents with large (> 100 kW) motors.

Symmetric motor cable should be used==>low Voltage loss at PE conductor.

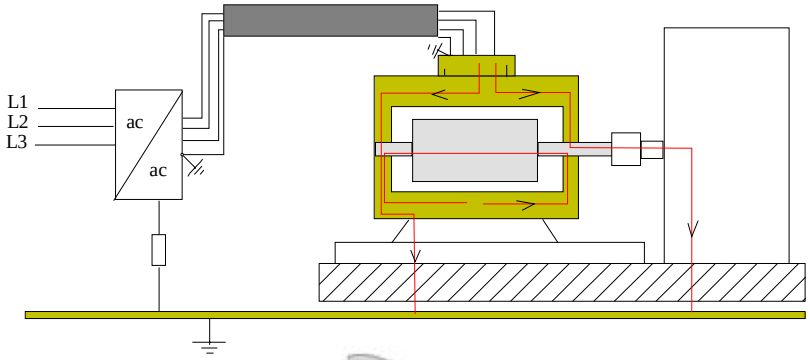


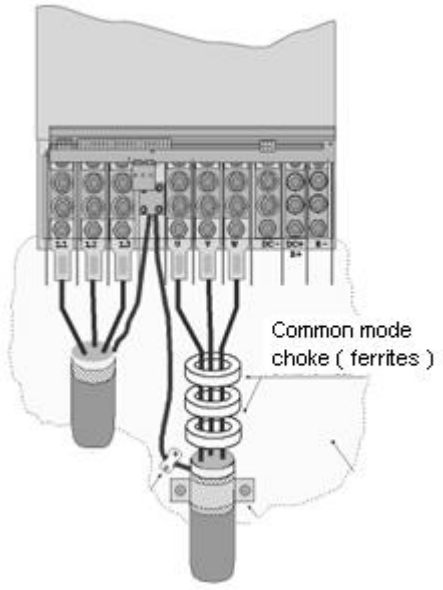
Potential of motor and machine should be same (low inductance !)

Insulated bearing at least at N-end.

Attenuation against common mode voltage / current. Individual choke/ du/dt-filter, common mode choke.

No " pig tail" earthings of screen of motor cable, but max. few cm to grounding. Best is sure 360 degree grounding directly to frame of cabin/ safety switch / motor.





THANK YOU