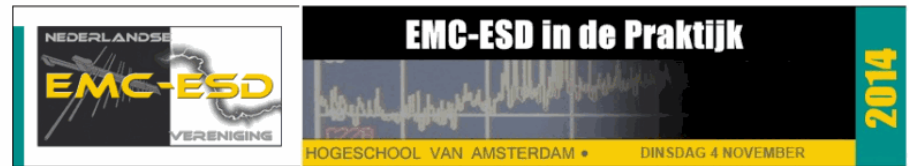


Motor bearing currents- what really helps

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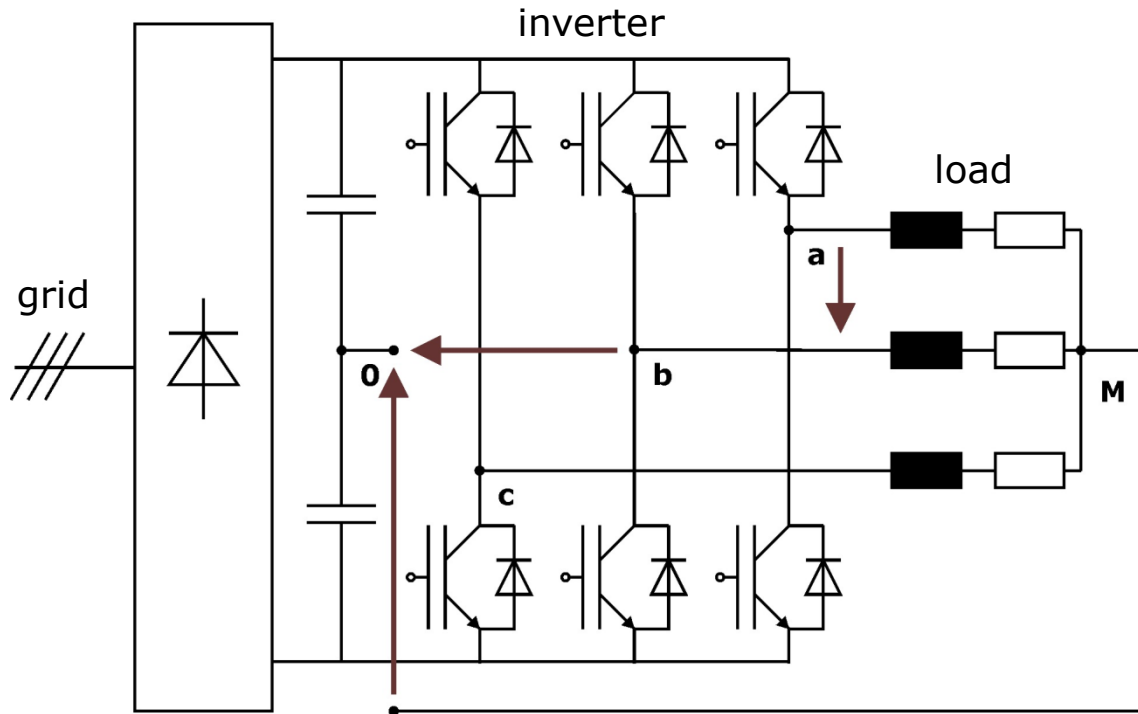


Agenda

- Differential mode and common mode
- Differential mode filters
 - Topologies
 - Effects
- Common mode filter
 - Topologies
 - Effects
- Summary

Differential and common mode

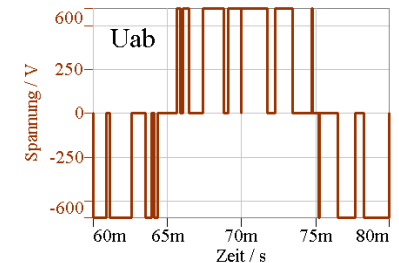
definition



The inverter generates no pure symmetrical voltage system.
A common mode voltage remains.

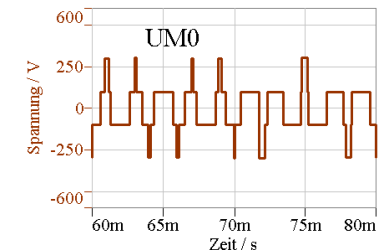
Differential mode voltage

$$u_{ab}(t) = u_{a0}(t) - u_{b0}(t)$$



Common mode voltage

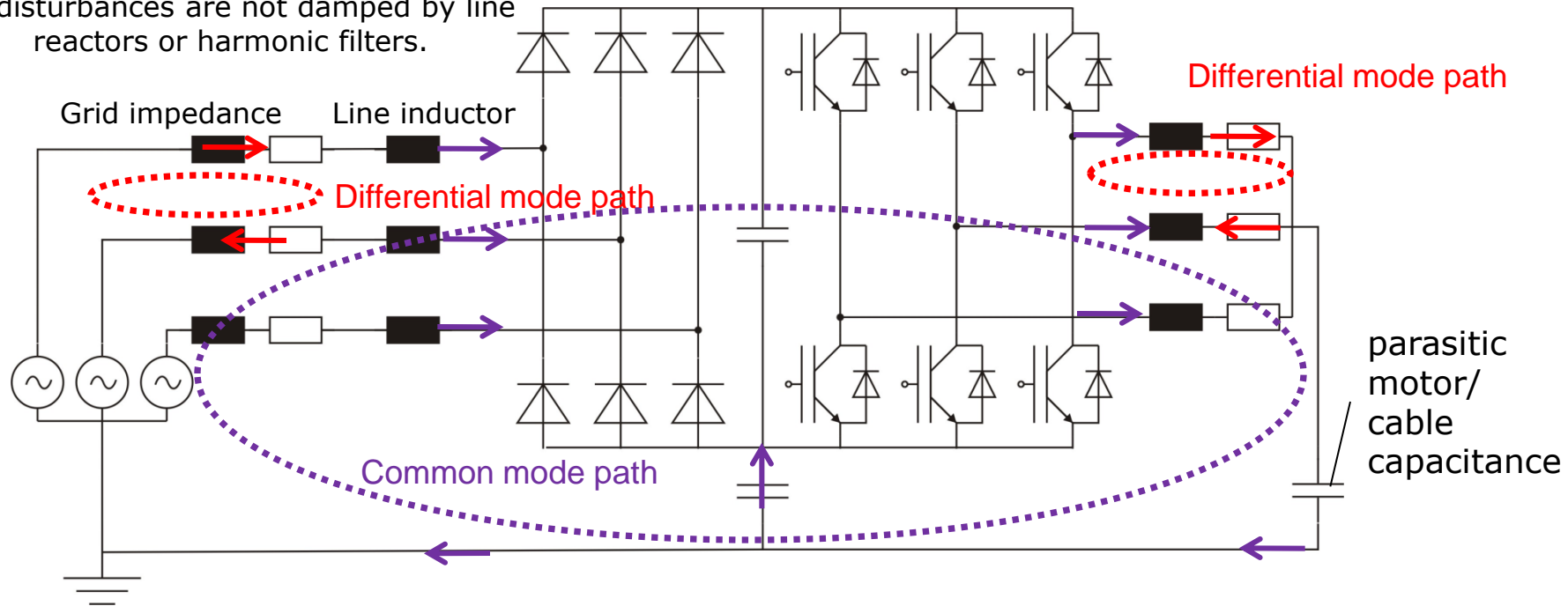
$$u_{M0}(t) = \frac{u_{a0}(t) + u_{b0}(t) + u_{c0}(t)}{3}$$



Distribution of disturbances

Differential mode and common mode

HF-disturbances are not damped by line reactors or harmonic filters.



The motor side inverter generates differential mode disturbances between the phases on motor and line side. Common mode currents are driven over the motor and cable capacitances to earth and back over the line side to the input rectifier and the DC link.

Distribution of disturbances

Differential mode and common mode

Differential mode:

current ripple (because of high switching frequency) -> high iron losses, stresses the inverter

voltage peaks (because of high dv/dt values and motor cable) -> stresses the motor insulation

high current peaks (because of parasitic capacitances) -> stresses IGBT's

Common mode

bearing currents -> stress and possibly destroy the bearings

- *Discharge current in lubrication film*

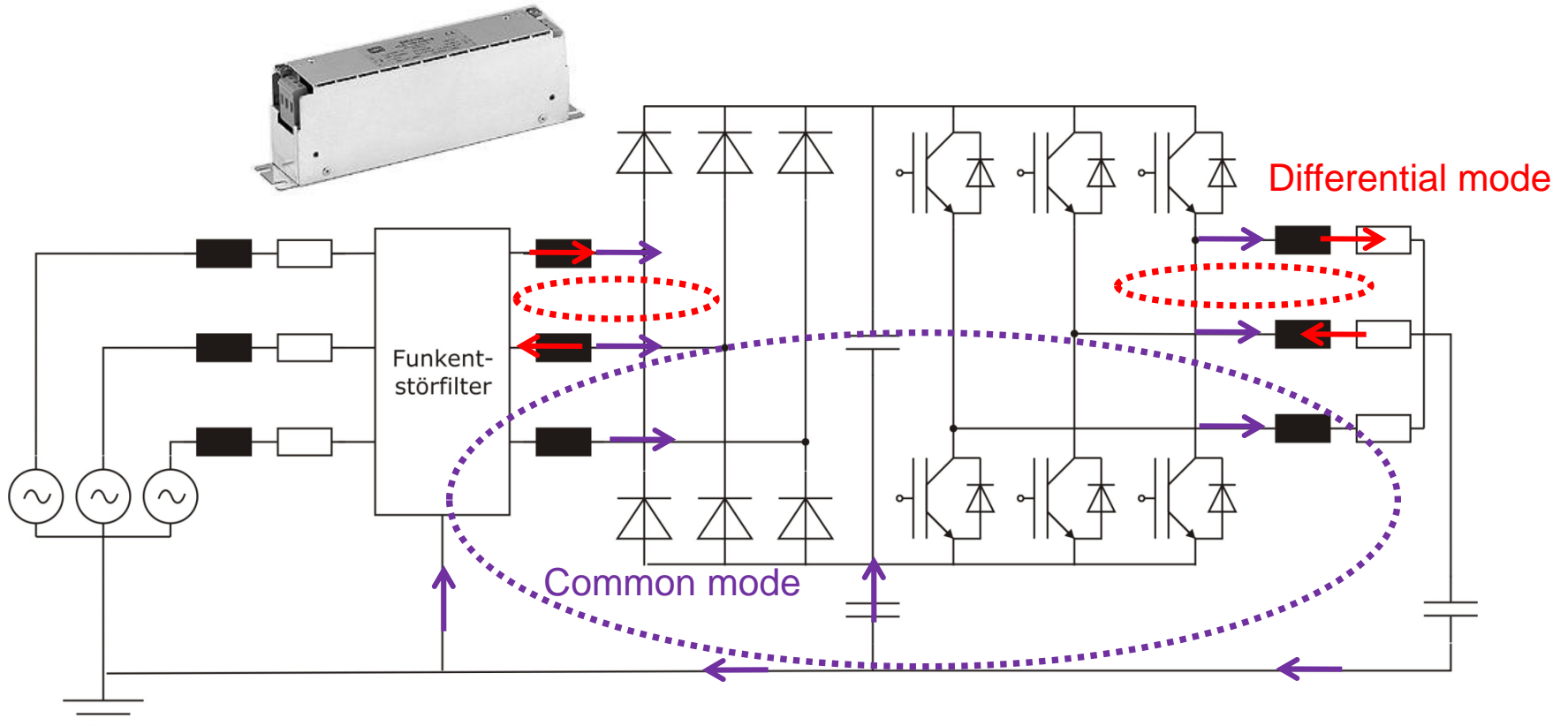
- *Motor-Earth current*

- *Rotor-Earth current*

high leakage currents -> possibly activate ground fault circuit interrupter (FI circuit breaker)

Distribution of disturbances

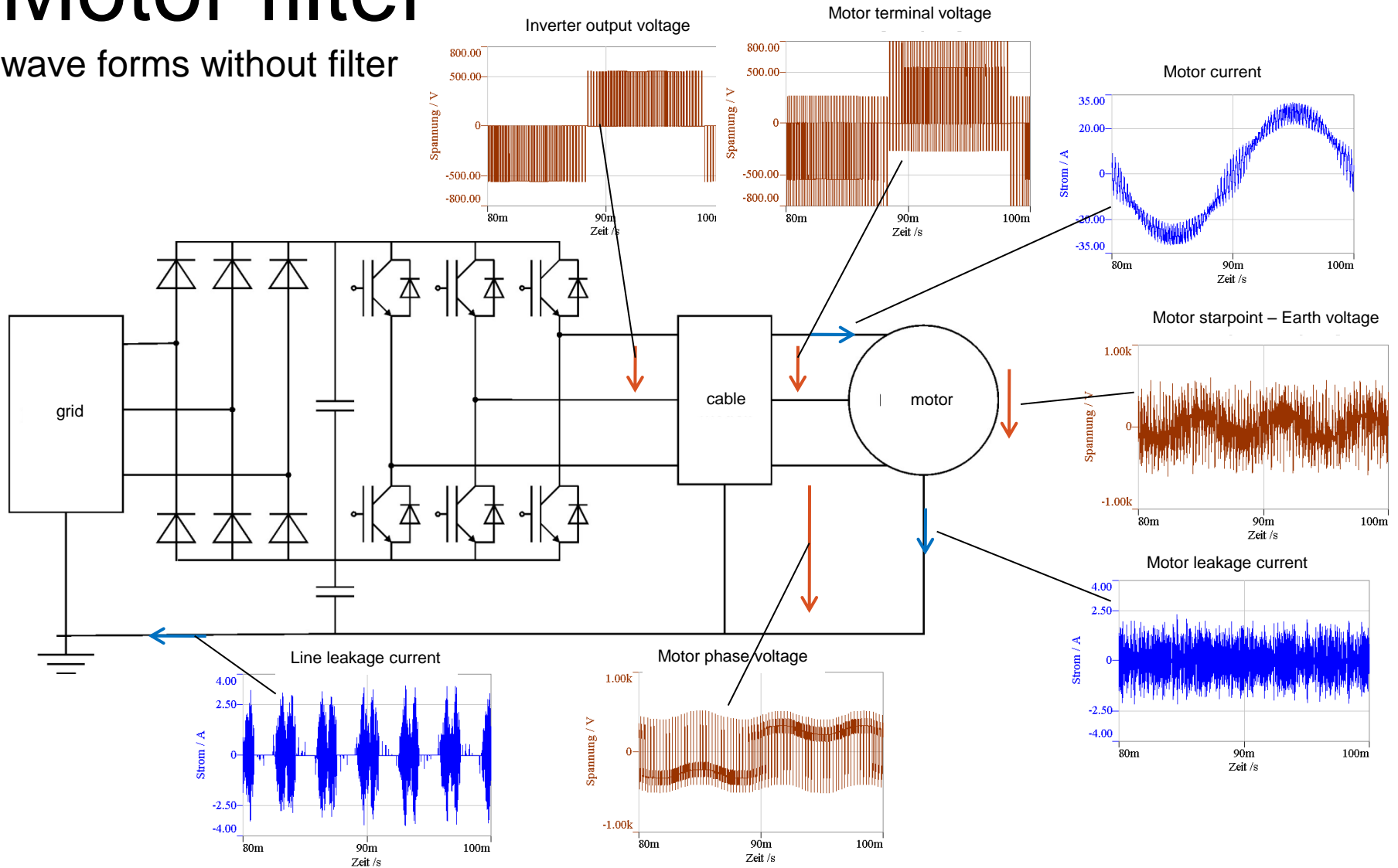
conducted emissions > 150kHz



The grid can be safely protected against disturbances of all frequencies with a line inductor or a harmonic filter and in addition an EMI-Filter.

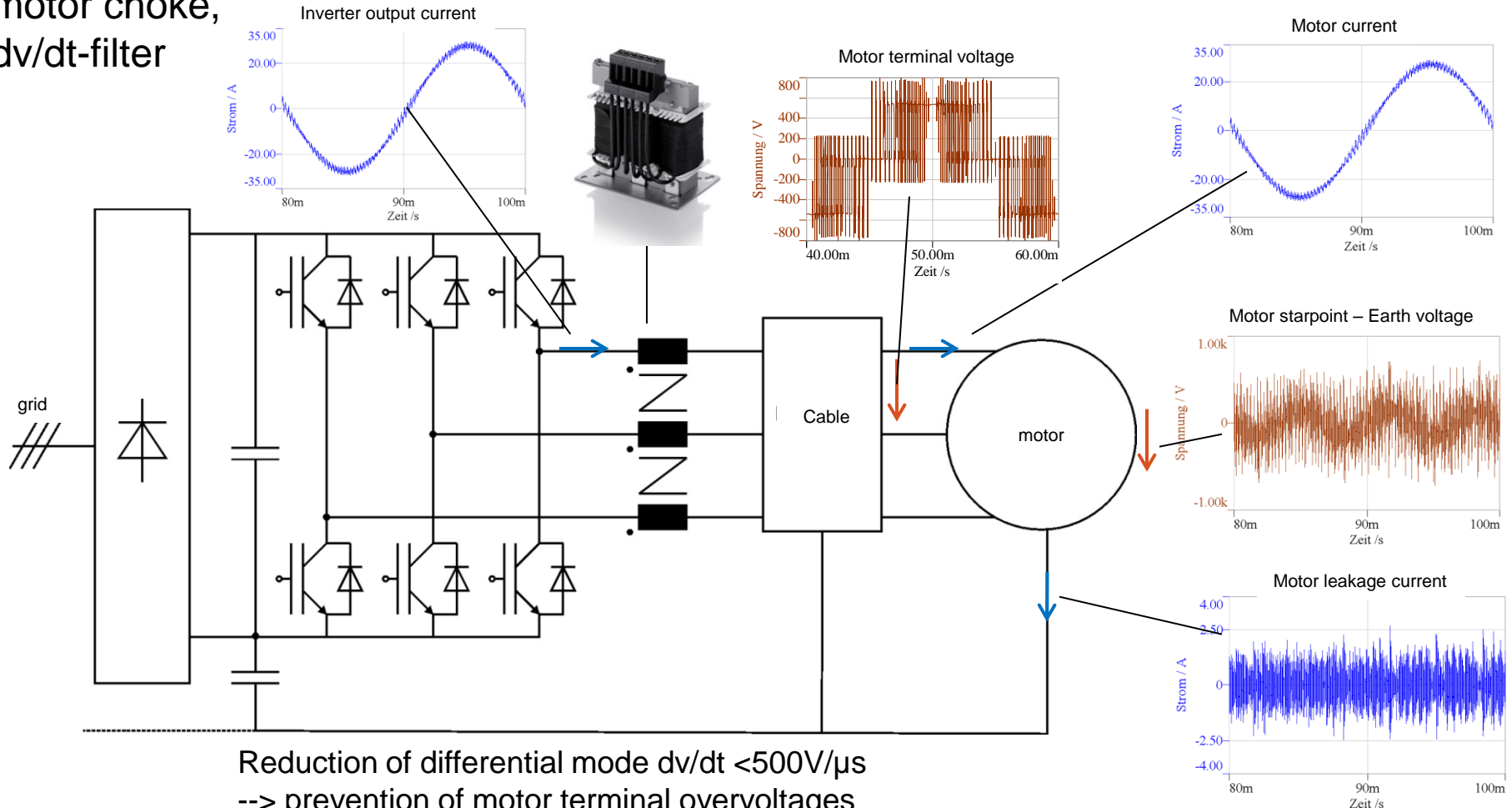
Motor filter

wave forms without filter



Differential mode motor filters

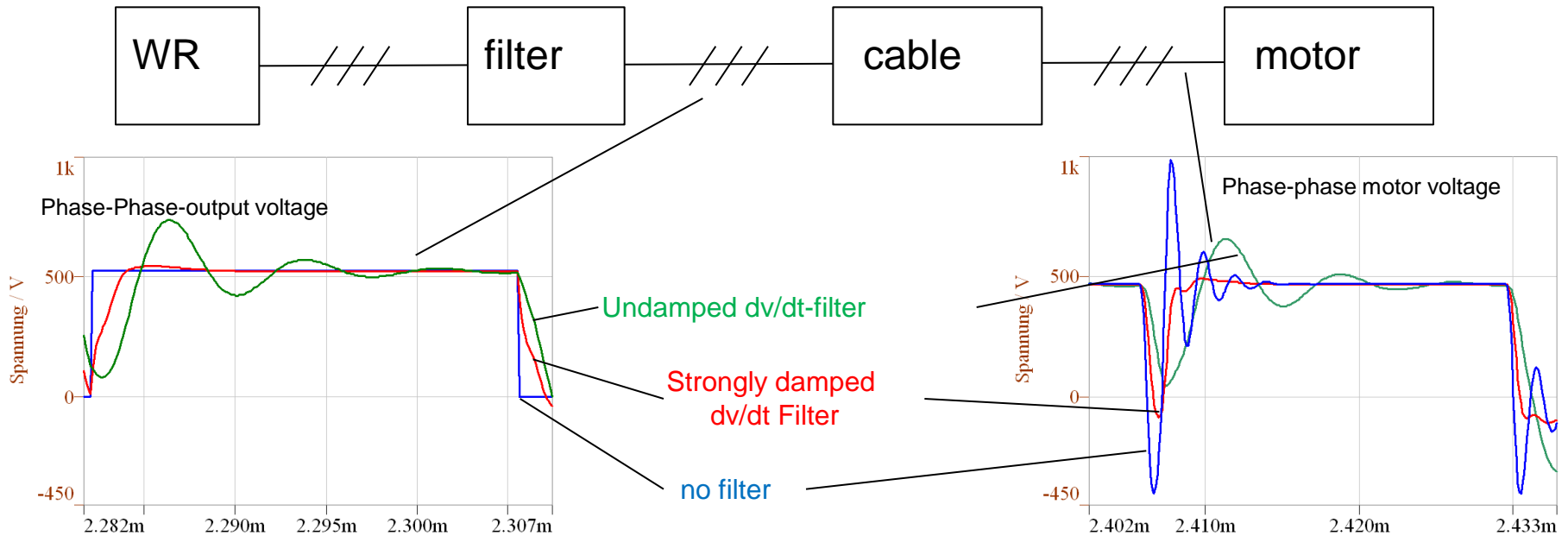
motor choke,
dv/dt-filter



Reduction of differential mode $dv/dt < 500V/\mu s$
 --> prevention of motor terminal overvoltages
 --> reduction inverter output current peaks

Differential mode motor filters

motor choke or dv/dt filter



No filter -> high overvoltage peaks because of long cable reflections
Undamped dv/dt filter -> defined overvoltage peaks , low dv/dt
Ohmic damped dv/dt filter -> low voltage overshoots, but high losses

Differential mode motor filters

why dv/dt filter? -> motor insulation

Motor insulation stress depends on amplitude and rise time of the motor voltage.

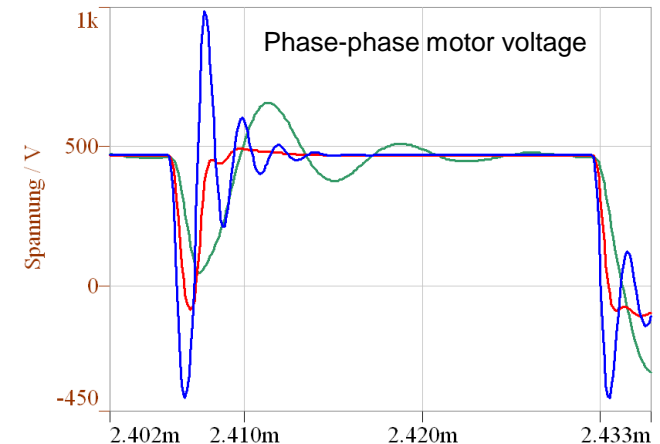
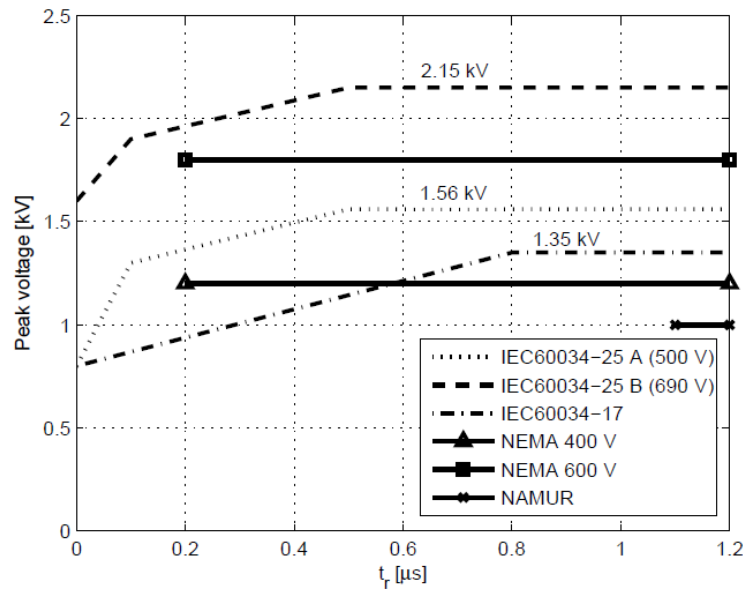
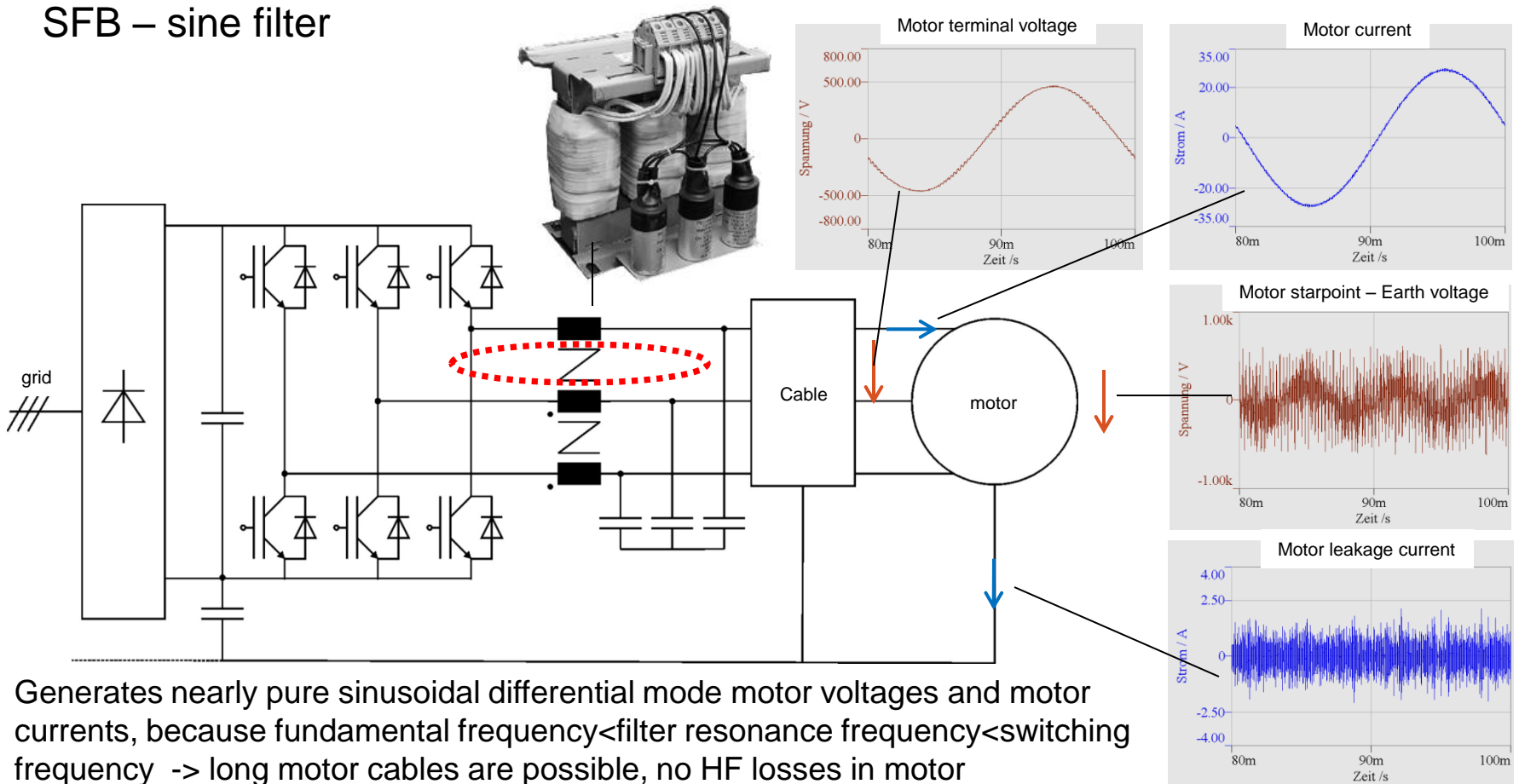


Figure 2.28 Limit curves of admissible motor terminal peak voltage.

Literature: PHD Thesis Norbert Hanigovski, 2005

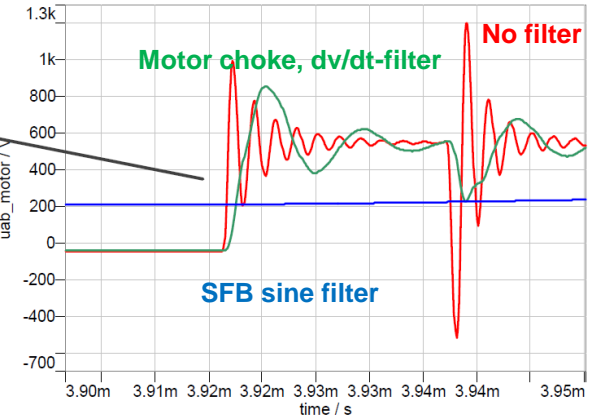
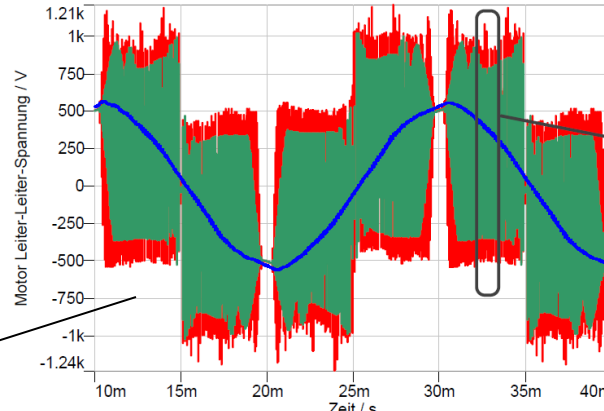
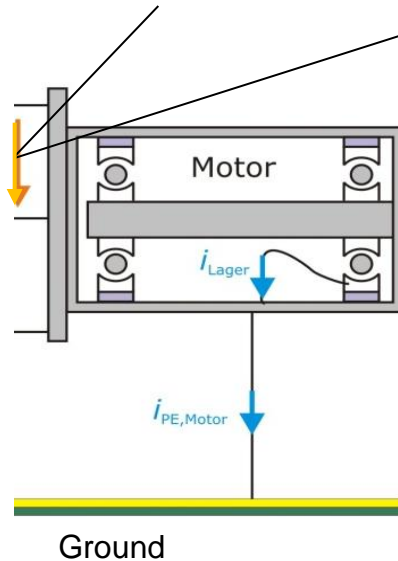
Differential mode motor filters

SFB – sine filter

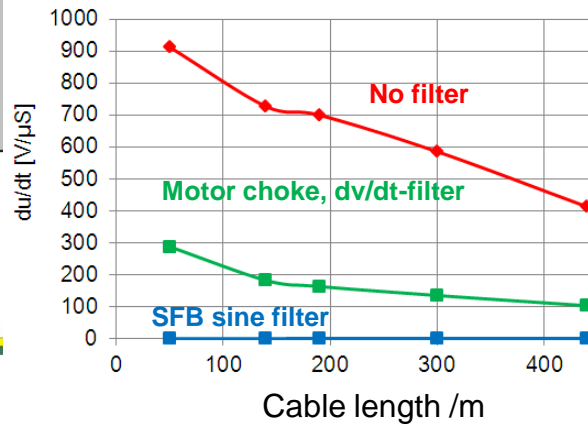


Effect of motor filters on DM motor terminal voltage

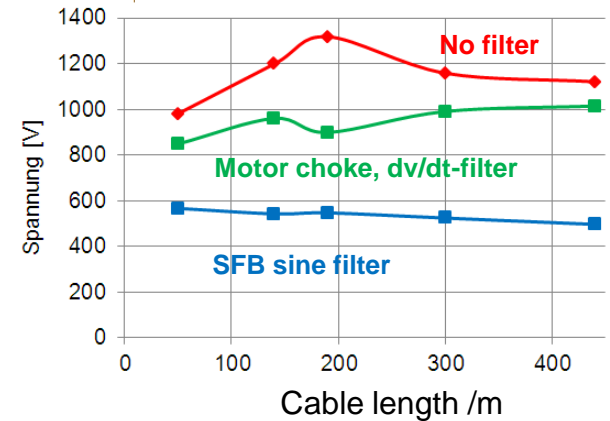
Differential mode motor terminal voltage



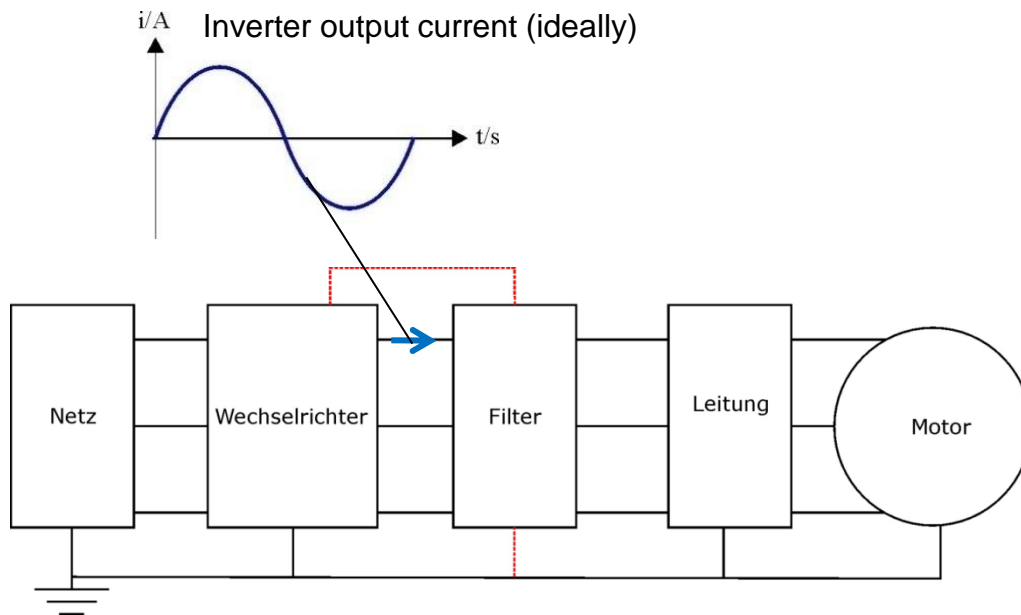
dv/dt



Peak voltage

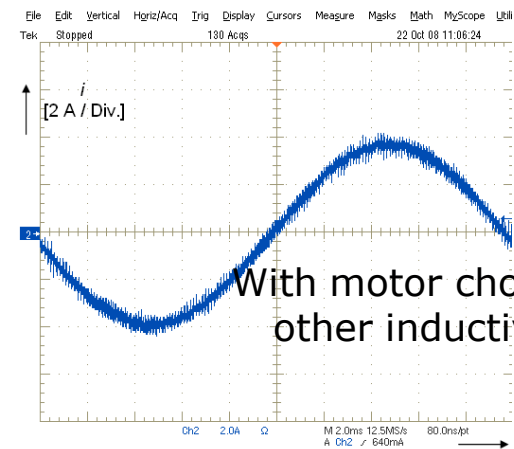
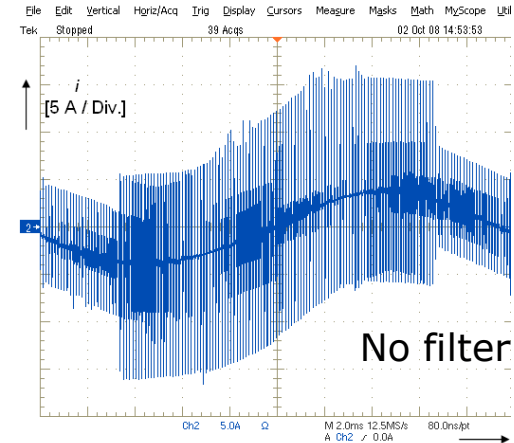


Effect of motor filters on inverter output current

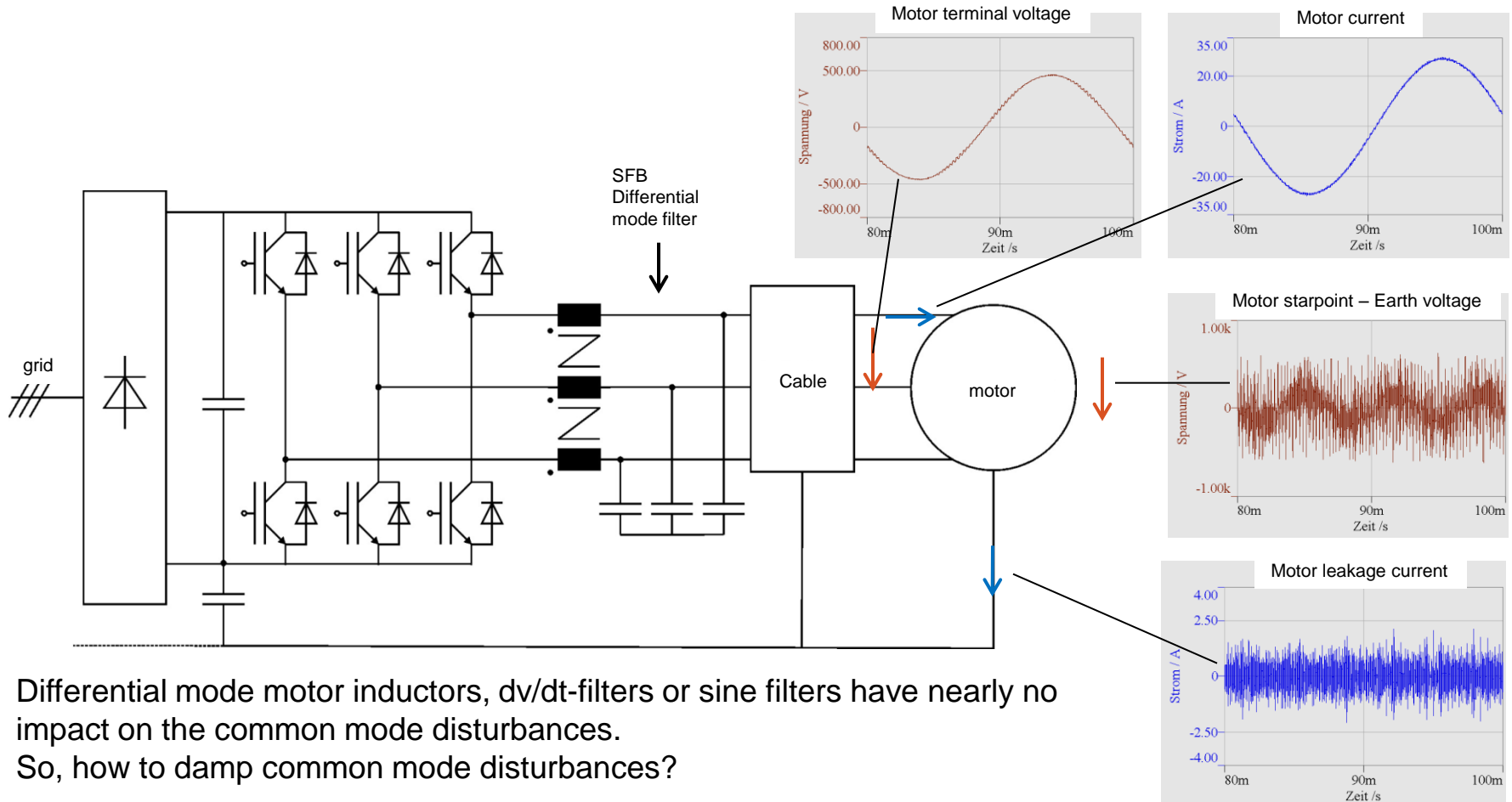


No filter: high output current peaks

With any inductive filter: elimination of output current peaks.
-> Reduction of inverter stress

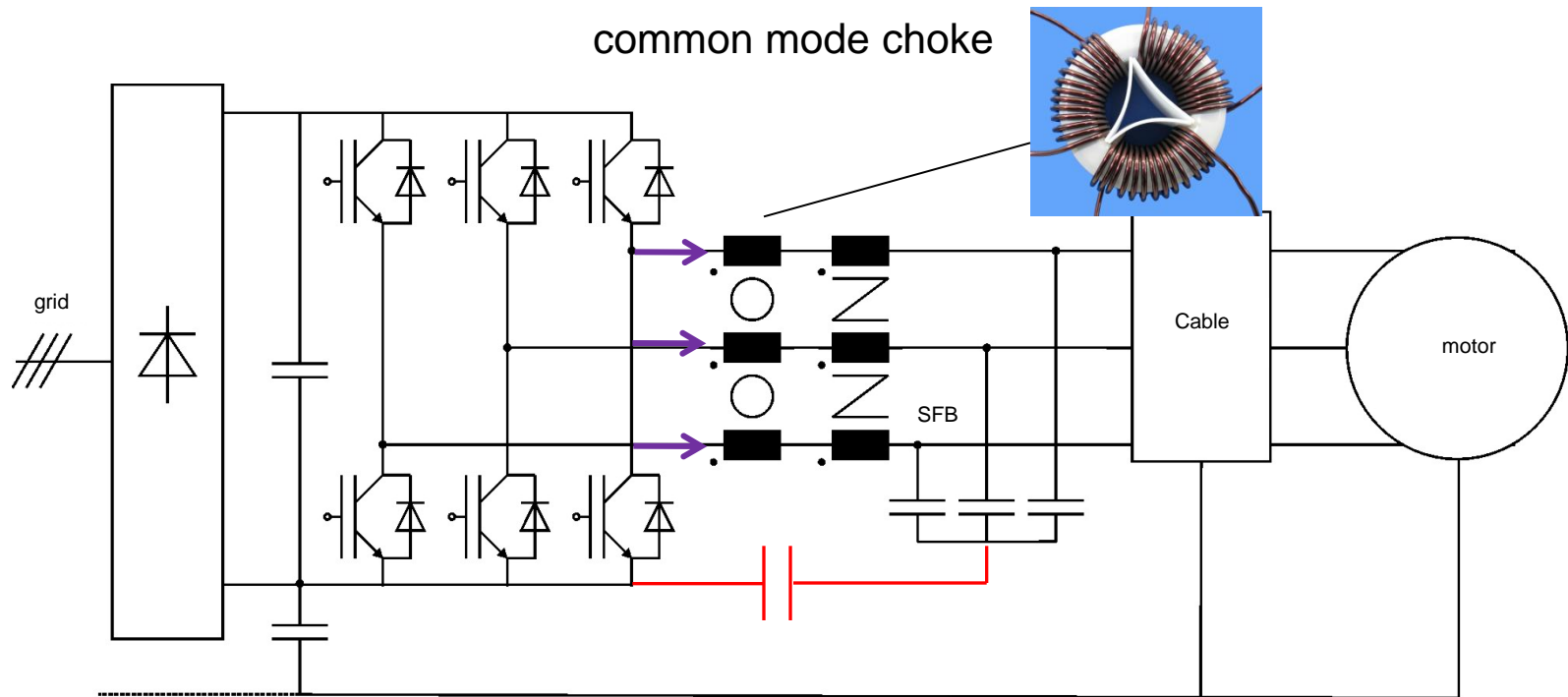


Common mode motor filters



Differential mode motor inductors, dv/dt-filters or sine filters have nearly no impact on the common mode disturbances.
So, how to damp common mode disturbances?

Common mode motor filters



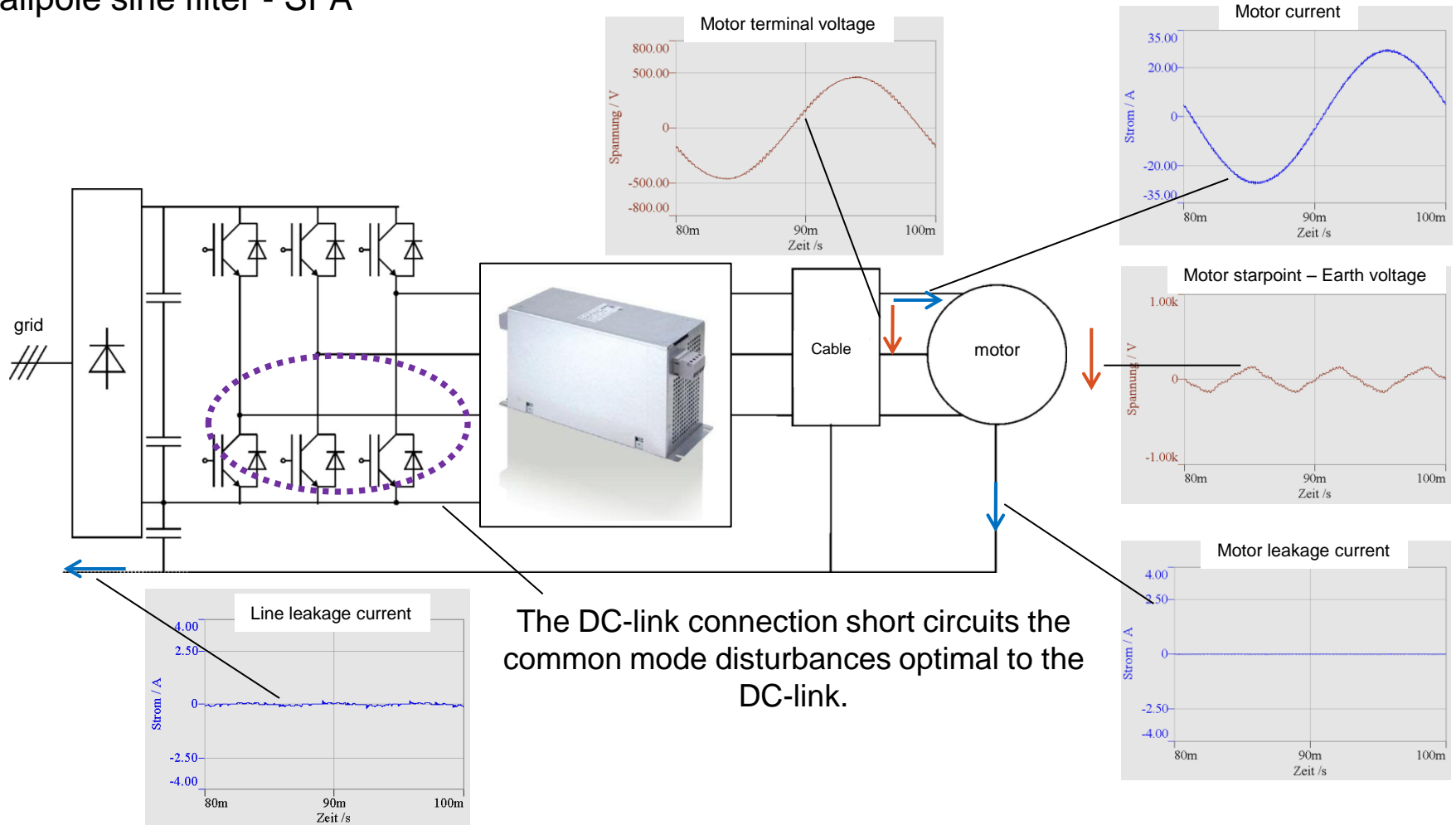
Simple damping of common mode currents.
 Damping depends on cable capacitance.
 Resonances possible. Switching frequency is not filtered. With a further connection to DC link, a **LC-filter** is formed with high common mode filter performance.

Literature:

SPS/IPC/DRIVES 2009, 24. – 26. November 2009 in Nürnberg
Erhöhte Spannungsbelastung von Motoren durch Umrichter-Ausgangsfilter
 Dr.-Ing. Benno Weis, Siemens AG, Erlangen, I DT SD R&D 3

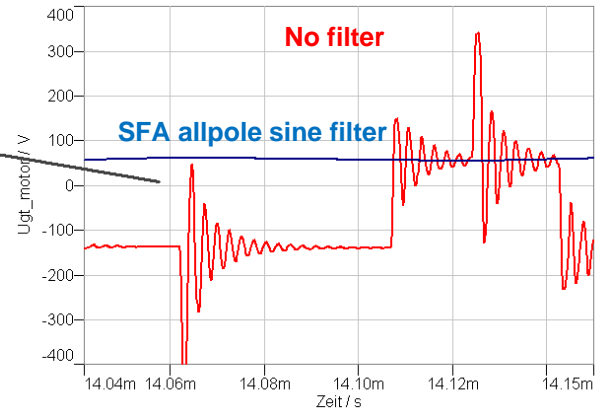
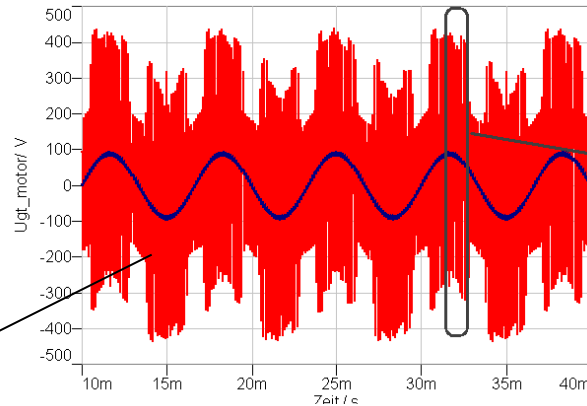
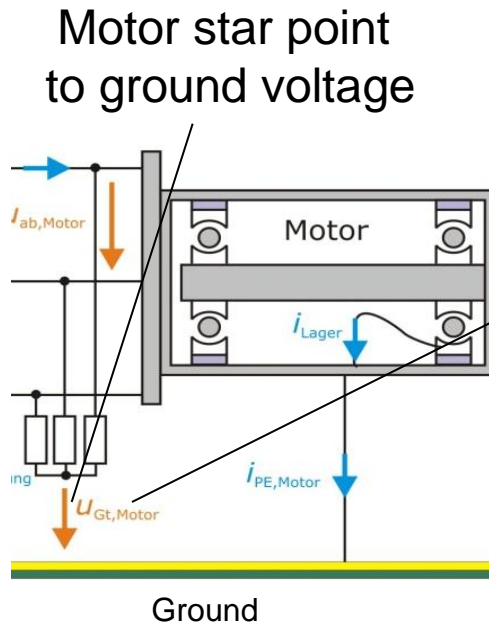
Common mode motor filters

allpole sine filter - SFA

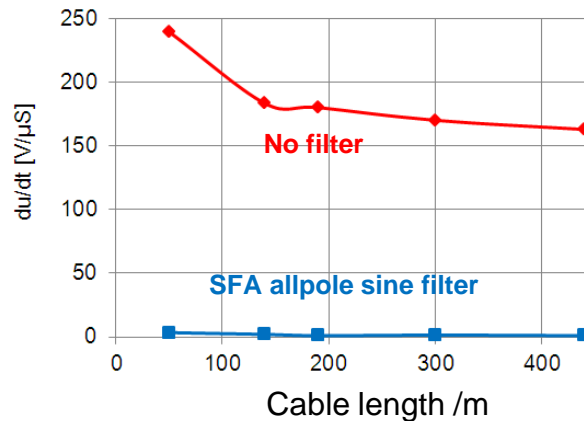


The DC-link connection short circuits the common mode disturbances optimal to the DC-link.

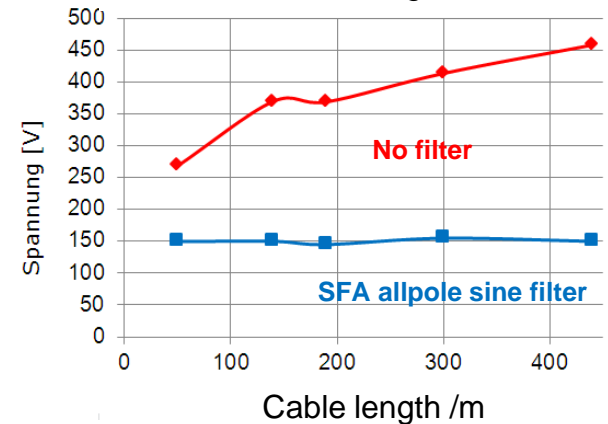
Effect of motor filters on motor star point voltage



dv/dt



Peak voltage

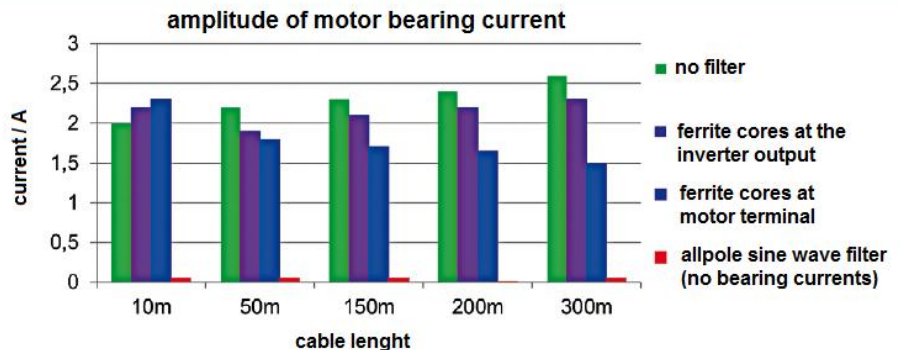
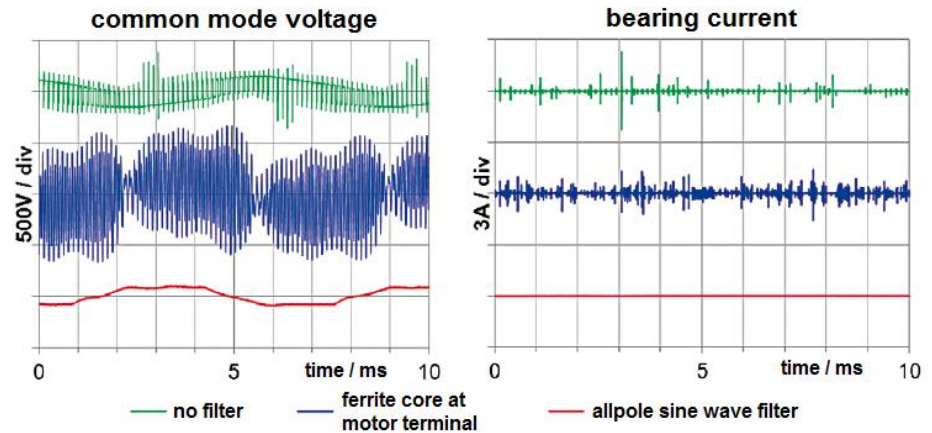


Effect of motor filters on motor bearing currents

No motor filter:
maximum bearing currents

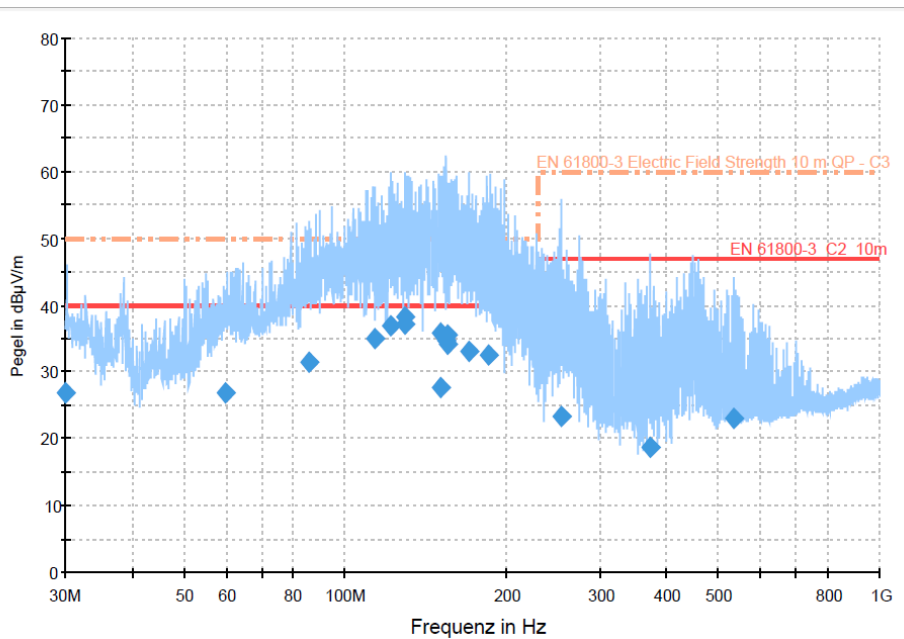
SFA allpole sine filter:
no bearing currents

Only differential mode motor filter:
small reduction of bearing currents by 5%-10%

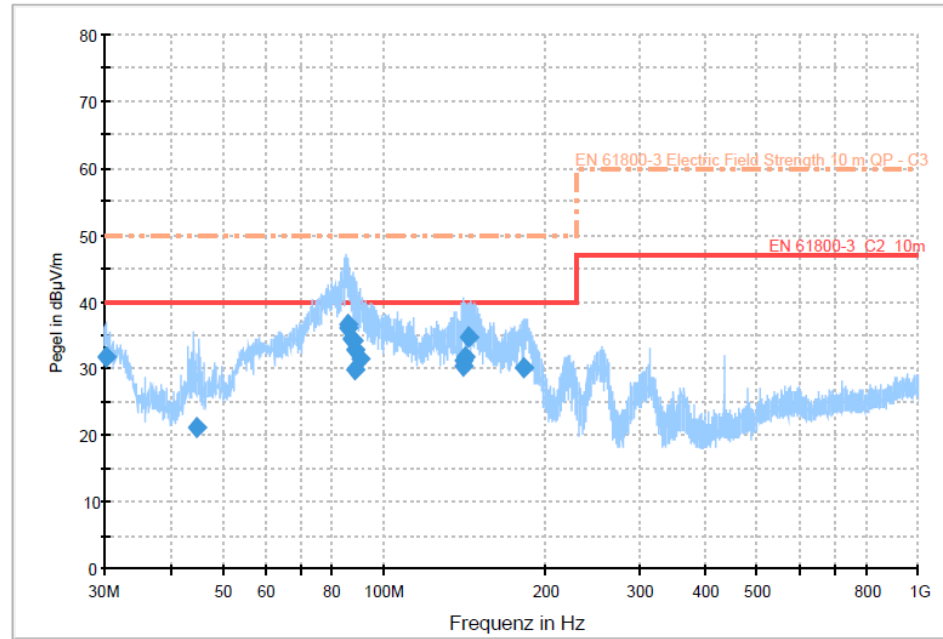


Effect of motor filters on radiated EMI on line side

shielded cable



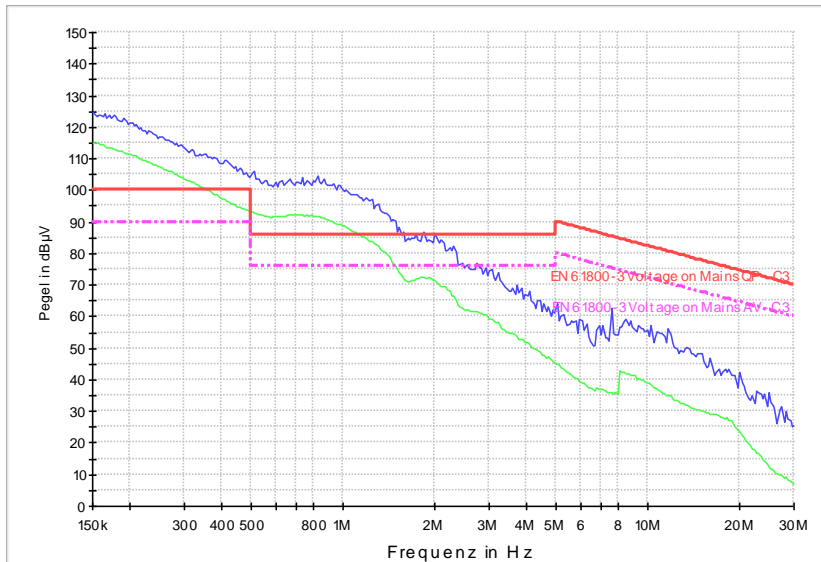
shielded cable + allpole sine wave filter



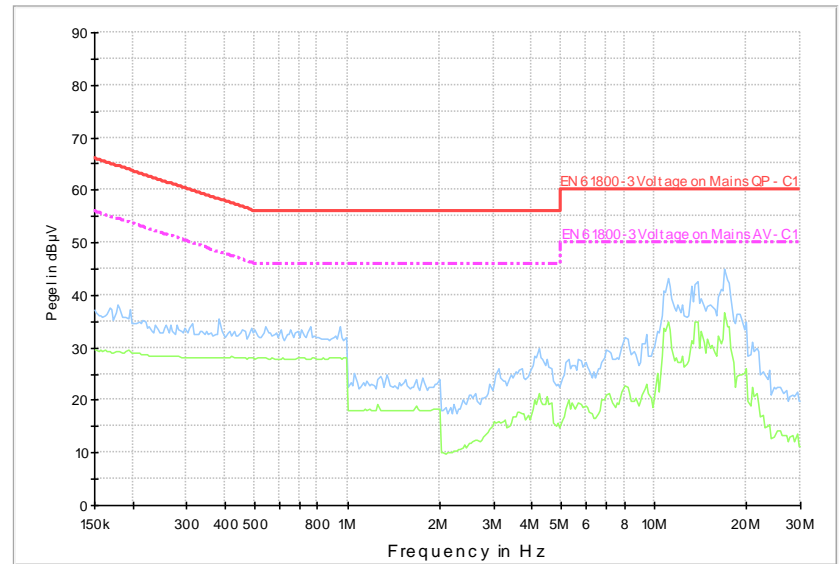
result: C2 without SFA - C1 with SFA.

Effect of motor filters on conducted EMI on line side

500m shielded cable



500m shielded cable + allpole sine wave filter



result: C2 without SFA - C1 with SFA.

Summary

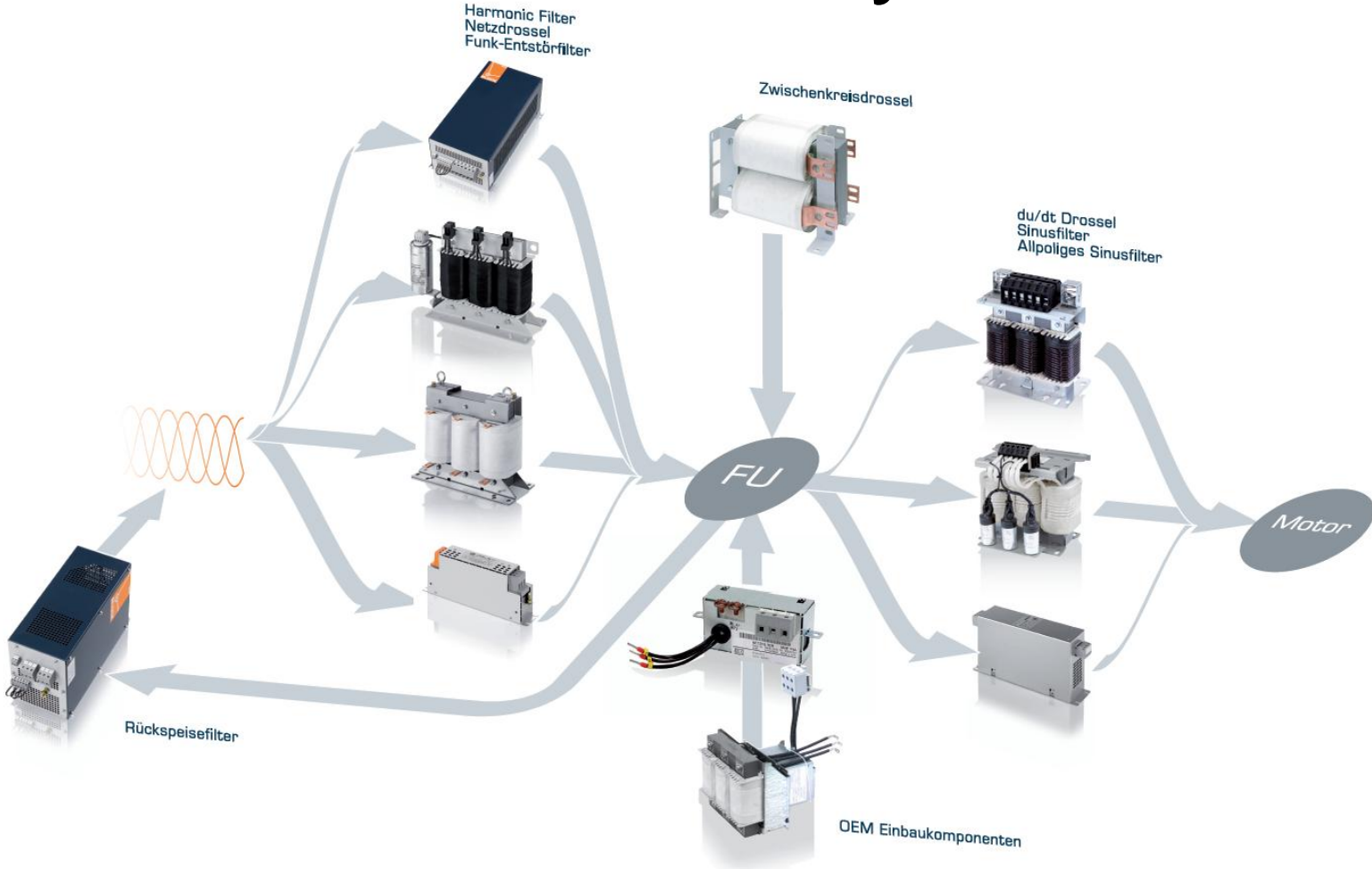
Differential mode filters reduce...

- dv/dt and motor peak voltages (less motor insulation stress)
- inverter output current peaks (less inverter stress)
- Low cost: Motor choke, High quality: sine filter SFB

Common mode filters reduce...

- dv/dt and peak shaft voltages (less motor insulation stress, elimination of bearing currents)
- conducted and radiated EMI, maybe shielded cables are not necessary
- High quality: allpole sine filter SFA

Summary



Thank you very much!

Question?

