

14 juni 2018
1931 Congrescentrum Den Bosch

POWER
ELECTRONICS 2018

elincom **BLOCK** 

FUTURE WINDING FOR NEXT POWER ELECTRONIC GENERATION
MALTE HEUERMANN, PRODUCTMANAGER EMC

AGENDA



Conventional
winding design

The new winding
design

Conclusion



FACTORY 1 VERDEN, GERMANY

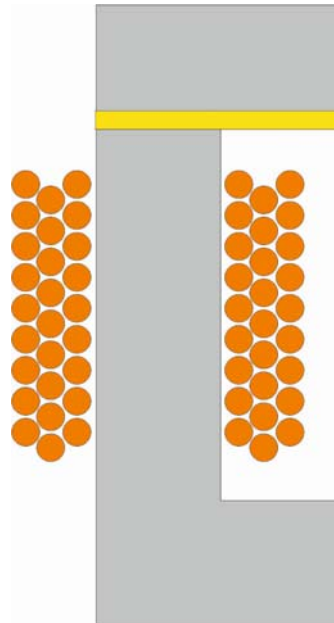


FACTORY 2 VERDEN, GERMANY



FACTORY 3, FRANKLIN PARK, ILLINOIS, USA

CONVENTIONAL WINDING DESIGN ROUND WIRE



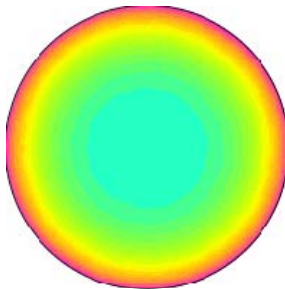
- Low cost (material & labour)
- Low filling factor
- High parasitic capacitance
- Low thermal conductivity
- Medium skin-and proximity losses
- Only for smaller currents

CONVENTIONAL WINDING DESIGN

ROUND WIRE

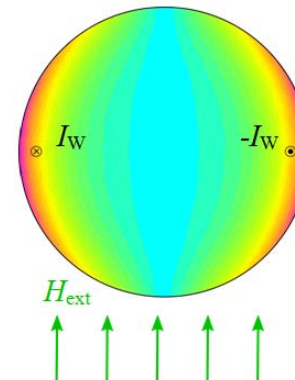
Skin-Effekt

- Current displacement due to internal fields



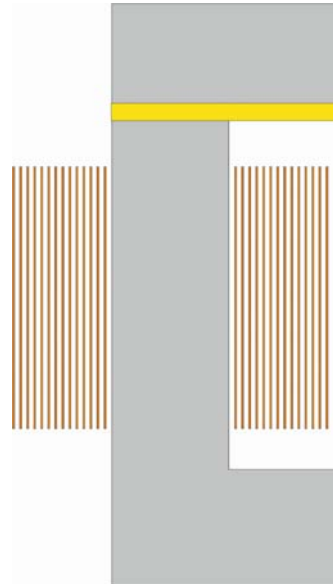
Proximity-Effekt

- Current displacement due to external fields



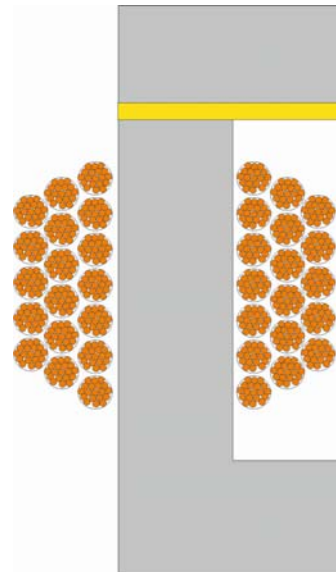
CONVENTIONAL WINDING DESIGN

FOIL WINDING



- Big cross section -- > High currents
- Low skin effect
- High proximity losses in the nearfield of airgaps
- Very high parasitic capacitance
- Low radial thermal conductivity
- High cost (insulation, labour)

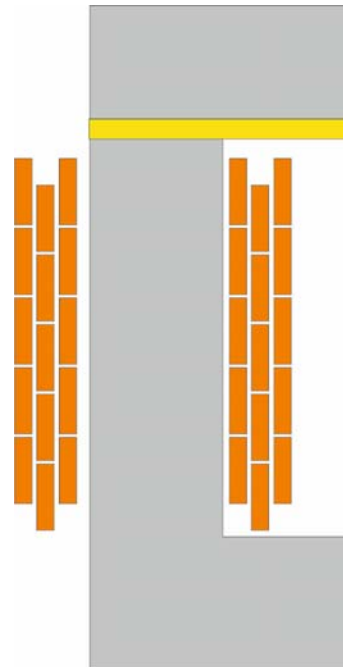
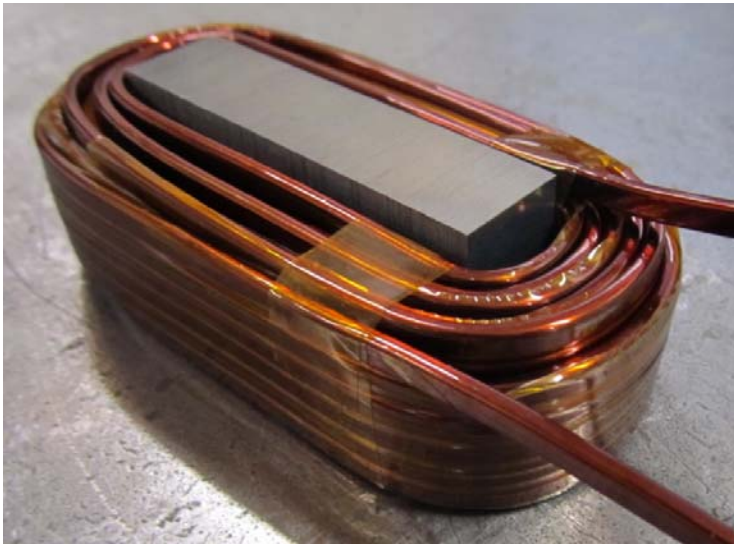
CONVENTIONAL WINDING DESIGN HF-LITZ WIRE



- Lowest skin- and proximity effect
- Very low filling factor
- Very low thermal conductivity
- High parasitic capacitance
- High costs (material & labour)

CONVENTIONAL WINDING DESIGN

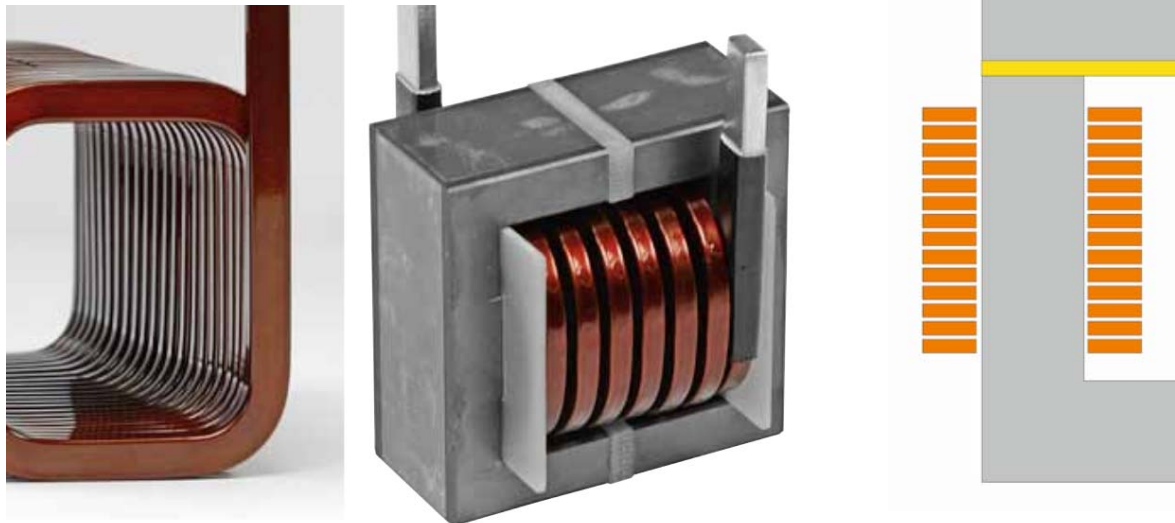
HORIZONTAL FLAT WINDING



- medium currents
- good fill factor
- High skin- & proximity losses
- High parasitic capacitance
- medium cost (material & labour)

CONVENTIONAL WINDING DESIGN

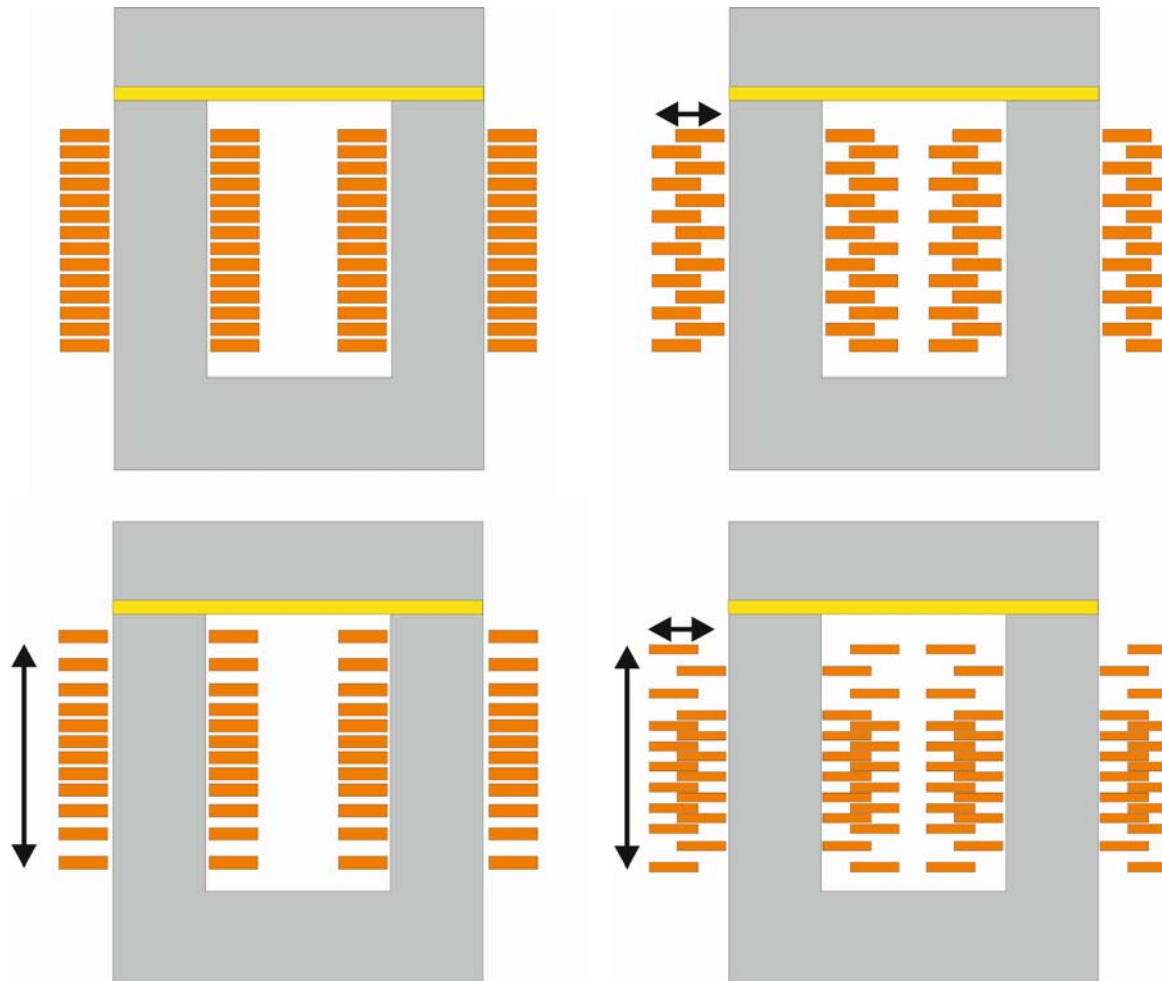
VERTICAL/EDGEWISE FLAT WIRE



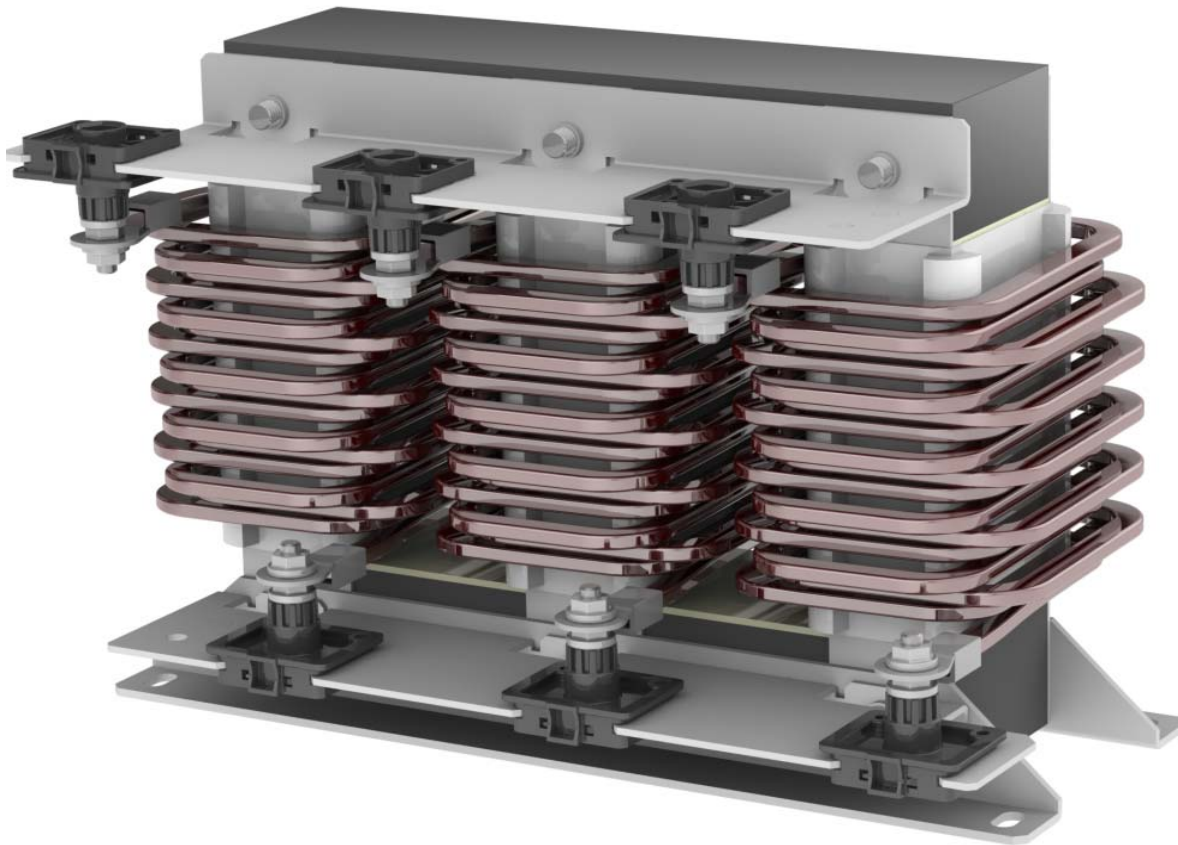
- medium currents
- good fill factor
- Low parasitic capacitance
- medium skin- & proximity losses
- medium cost (material & labour)

THE NEW WINDING DESIGN

PRINCIPLE



THE NEW WINDING DESIGN
LONG LIFE TIME



- Nearly no insulation material required
 - Aging effects in the insulation materials no longer occur
- > drastically increased life time .

THE NEW WINDING DESIGN

LOW LOSSES

Varying the conductor spacing in the winding structure:

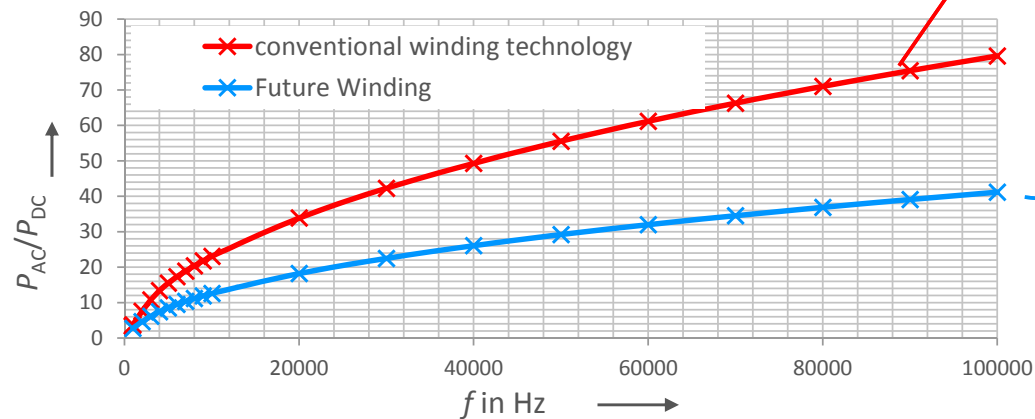
- effectively reduces proximity losses (The proximity effect is reduced proportionally to the distance between the conductors)
- represents a potentially cost-effective alternative to expensive high-frequency litz wires in some applications

$$\hat{H} = \frac{\hat{i}}{2 \cdot \pi \cdot r} \sim \frac{1}{r}$$

$$P_{\text{Prox}} = \frac{l}{\kappa} \cdot \hat{H}_{\text{ext}}^2 \cdot 2\pi \cdot r_{\text{cu}} \operatorname{Re} \left\{ k \cdot \frac{I_1(kr_{\text{cu}})}{I_0(kr_{\text{cu}})} \right\}$$

$$P_{\text{Prox}} \sim \frac{1}{r^2}$$

r - distance between conductors

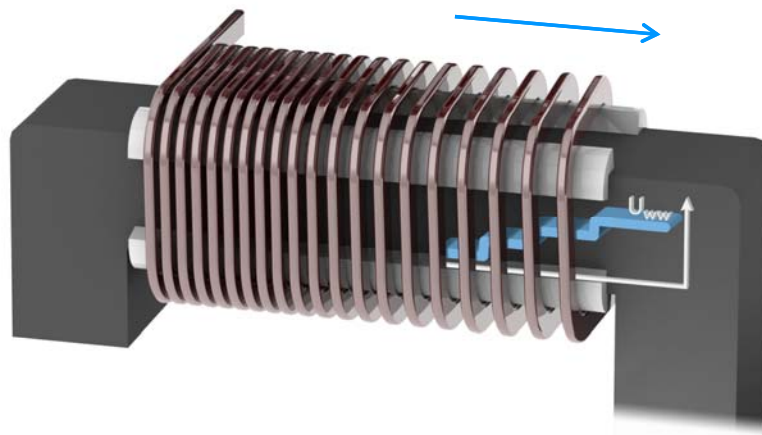


Loss comparison between classical (edge wise) and new winding design (edgewise with different distance from core of each winding).

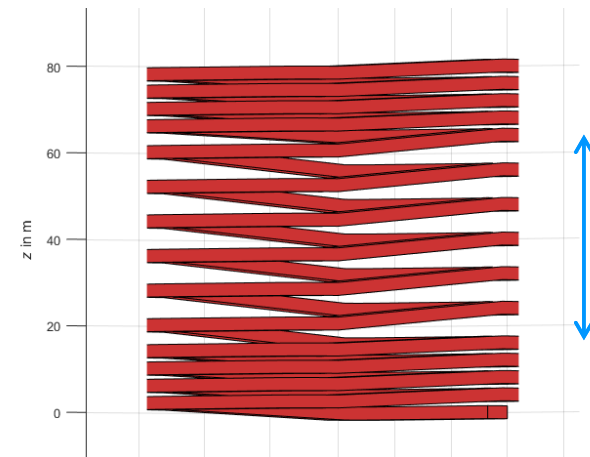
THE NEW WINDING DESIGN POTENTIAL CONTROL

Spreading the winding:

- much lower parasitic capacitances
- transient overvoltage control (i.e. due to voltage reflections)
- conductor insulation is protected. No short circuits between windings



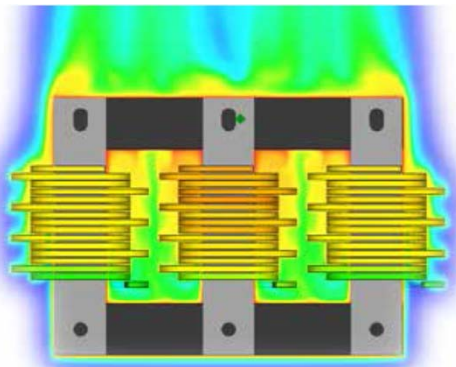
By the distance between windings the voltage potential can be controlled.



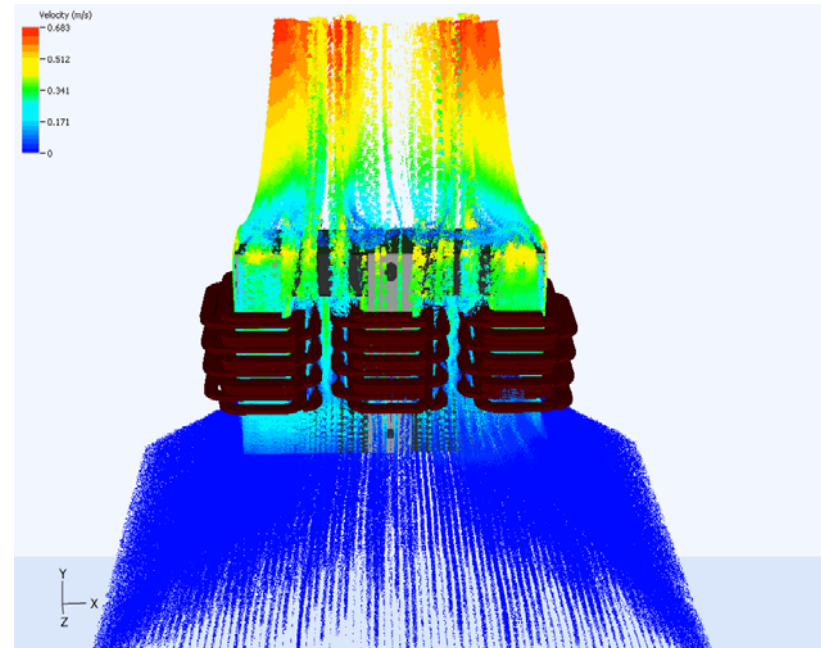
THE NEW WINDING DESIGN COOLING

increased conductor surface and spread of the winding + cooling ducts:

- optimal cooling of the entire product.
- The new winding technology especially shows off its strengths with forced air cooling.

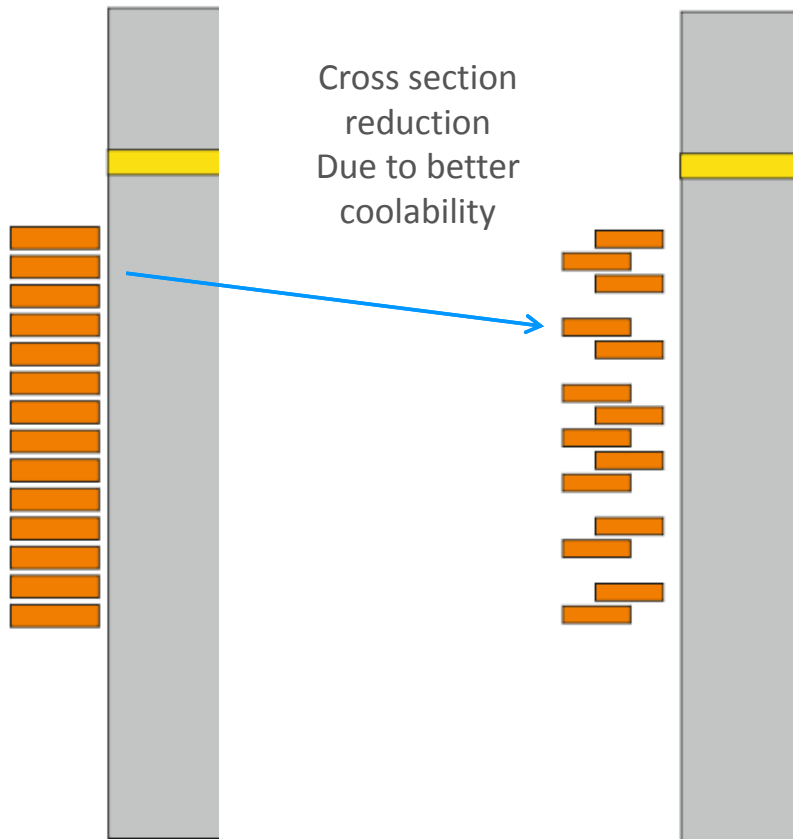


The thermal behavior of the new winding is essentially better than of conventional winding design



THE NEW WINDING DESIGN

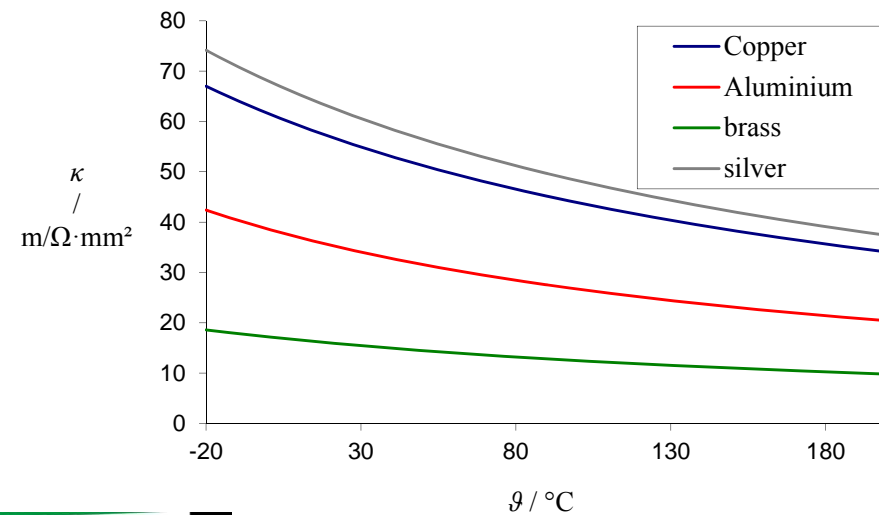
HIGH CURRENT DENSITY



conductor's heat-emitting surface is exposed to the prevailing cool air flow.

- > high current density
- > reducing structural volume, weight and costs

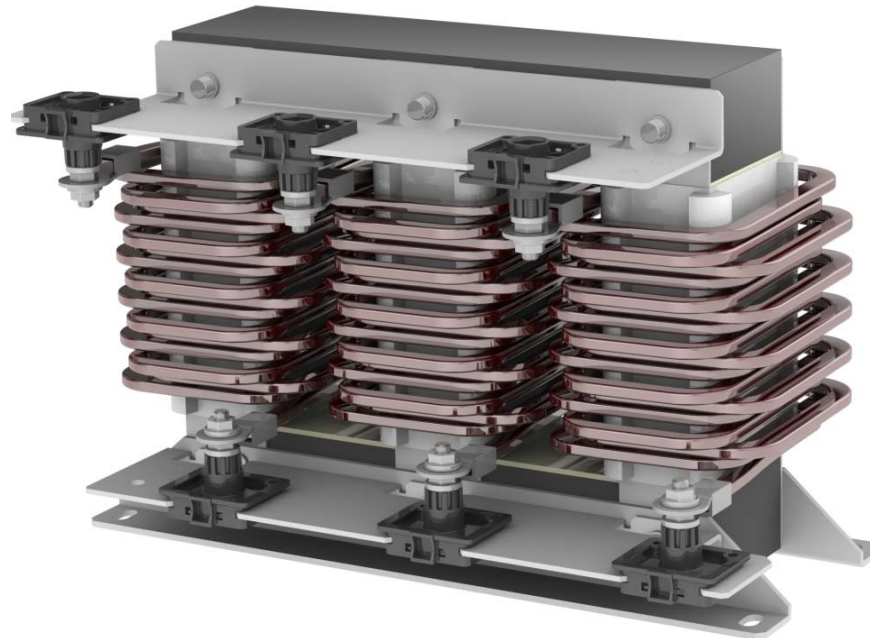
OR: increasing efficiency by cooler wire



THE NEW WINDING DESIGN

LOWER COSTS

- nearly no insulation material
 - automatically manufactured winding
 - Small cross section due to high current density
- > cost can be by reduced 30%

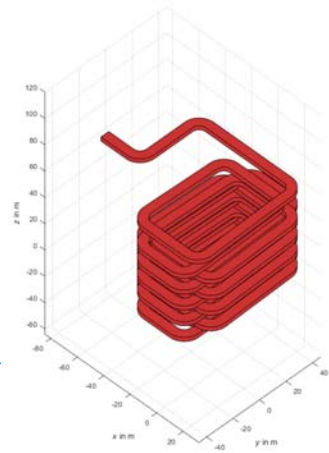


THE NEW WINDING DESIGN

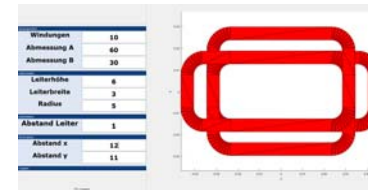
AUTOMATED DIGITAL DEVELOPMENT PROCESS



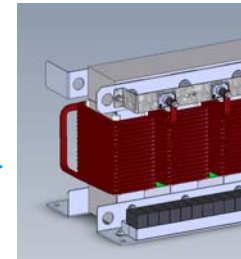
Inductor calculation



Machine program



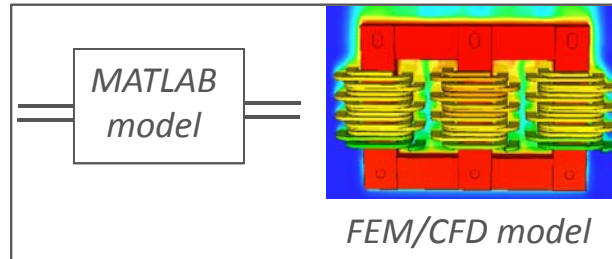
3D-CAD



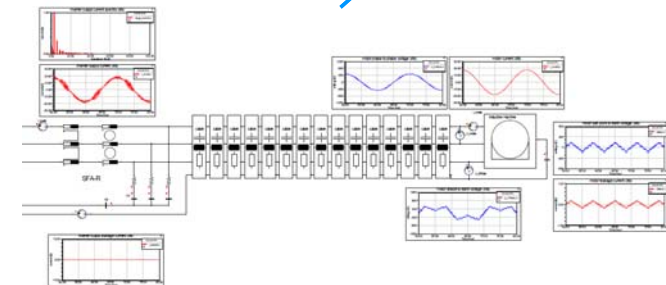
Product



Digital twin



Simulation



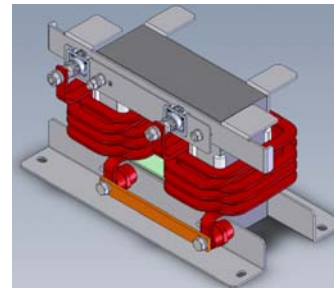
APPLICATIONS

Application: Line reactor



Other applications:

- DC-Link chokes, Buck- / Boost converter chokes



Application: sine filter



Application: allpole sine filter



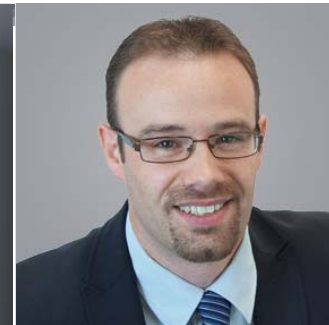
Transformers,...

CONCLUSION

A new winding technology was shown in this paper. The new winding design gives advantages in terms of life time, losses, voltage potential control, cooling capability, current density and costs. It can be used for inductors or transformers.



NOW WHAT CAN WE DEVELOP FOR YOU?



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