ADVANCED COMPACT MEDIUM FREQUENCY TRANSFORMERS

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AGENDA

System Topologies

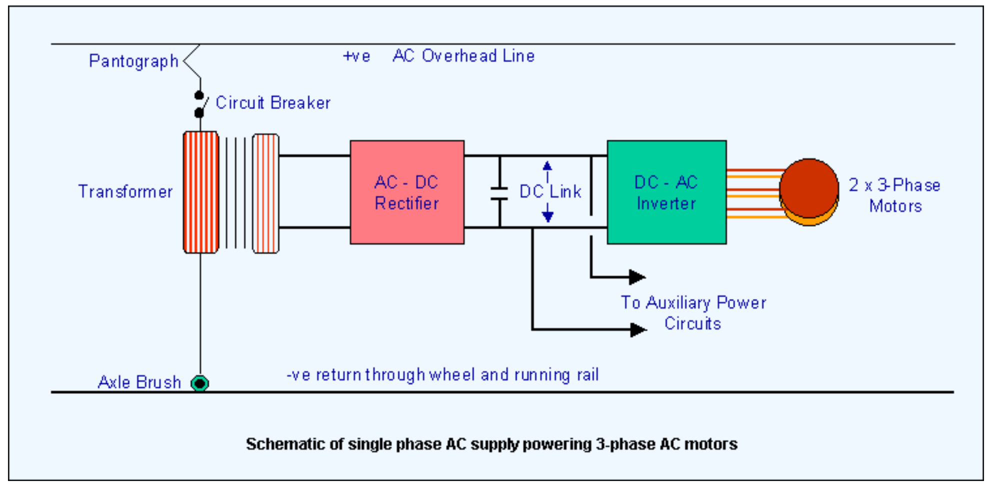
State of the art MF-Transformers

Next generation MF-transformer

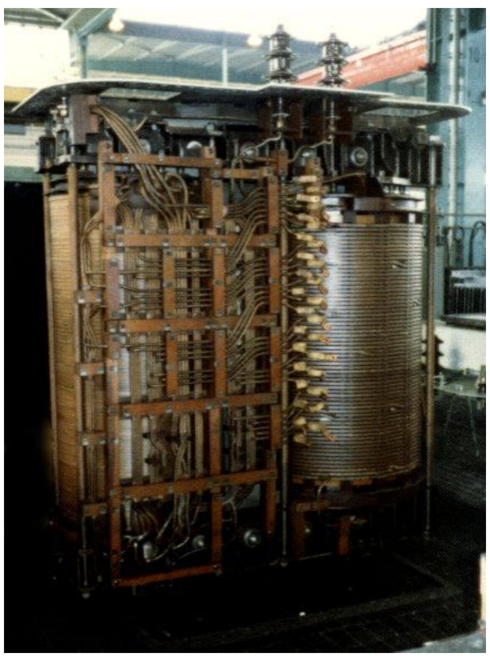
Conclusion

REQUIEREMENTS FOR MF-TRANSFORMERS IN RAILWAY
SYSTEM TOPOLOGIES

Classical system:
One big 16 2/3Hz transformer supplies all systems.



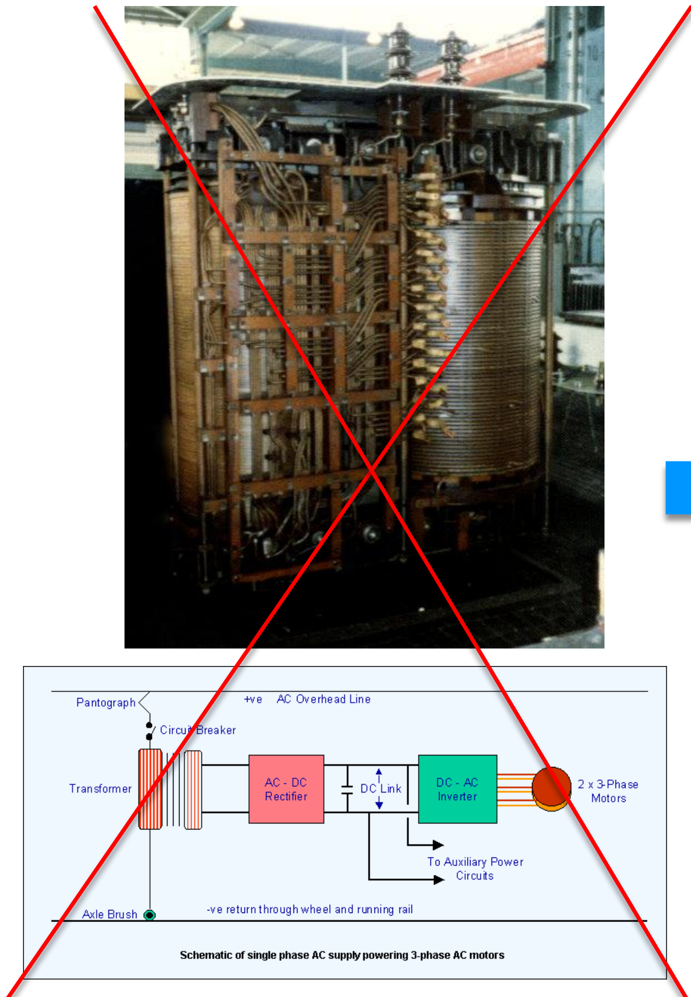
picture: railway-technical.com



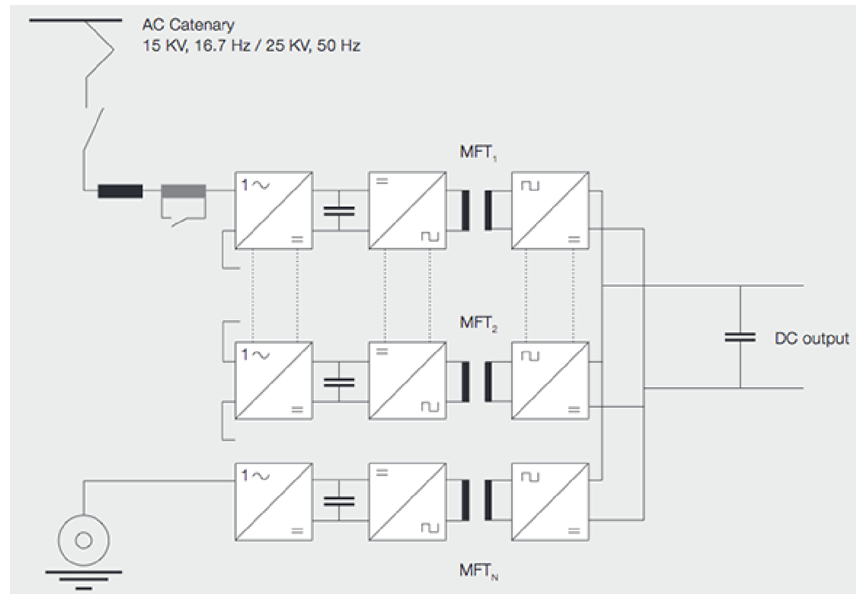
picture:Wikipedia

→ Big and bulky.

REQUIEREMENTS FOR MF-TRANSFORMERS IN RAILWAY
SYSTEM TOPOLOGIES



More electric train:
low frequency transformer is replaced by MF-transformers



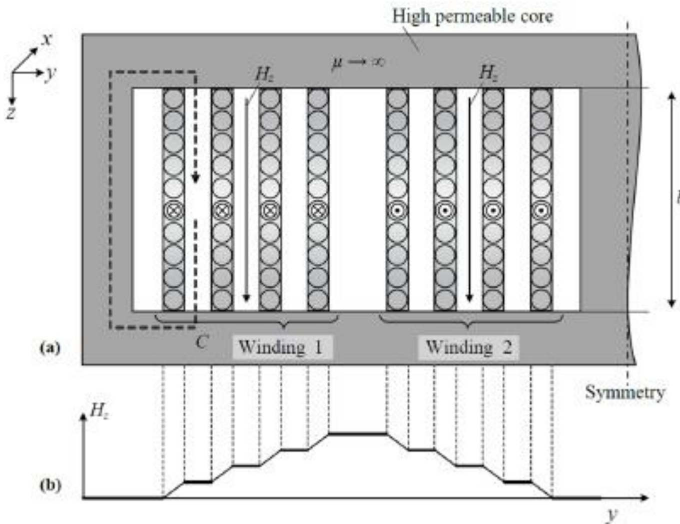
MF-transformers (3kHz-24kHz) substitute the big 16 2/3Hz transformers

→Much lower weight and size.

REQUIEREMENTS FOR MF-TRANSFORMERS IN RAILWAY

AC-COPPER LOSSES

BLOCK



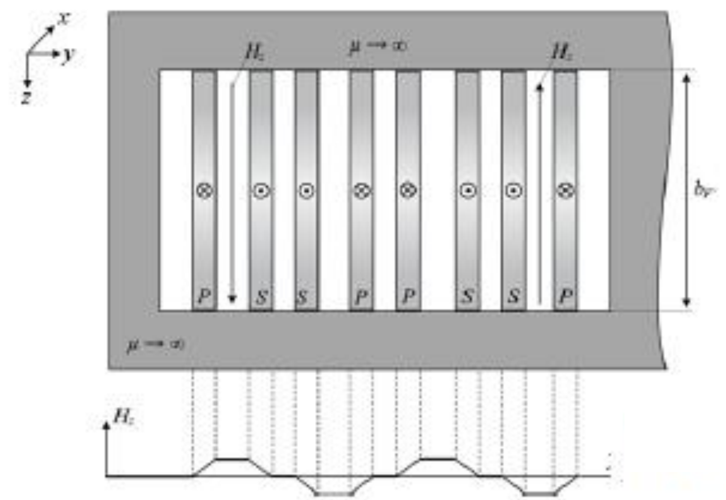


Fig. 1. Effect of interleaving [1]

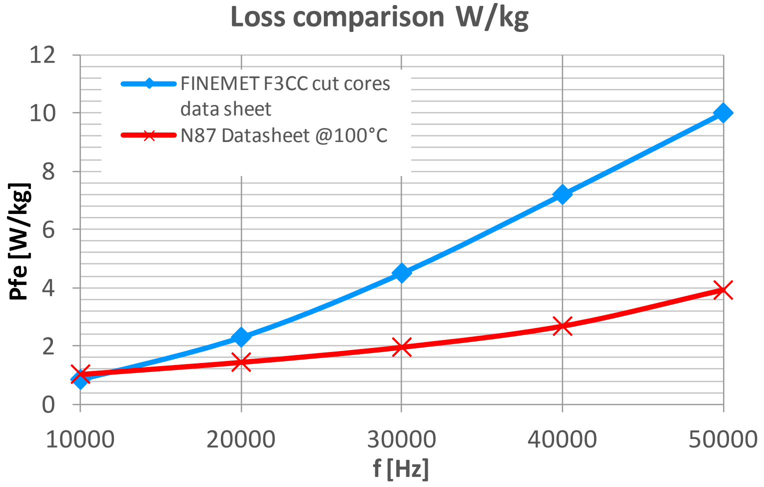
- Designing MF-transformers is much more challenging then designing low frequency transformers. Especially copper AC-losses due to proximity- and skin-effects have high impact.

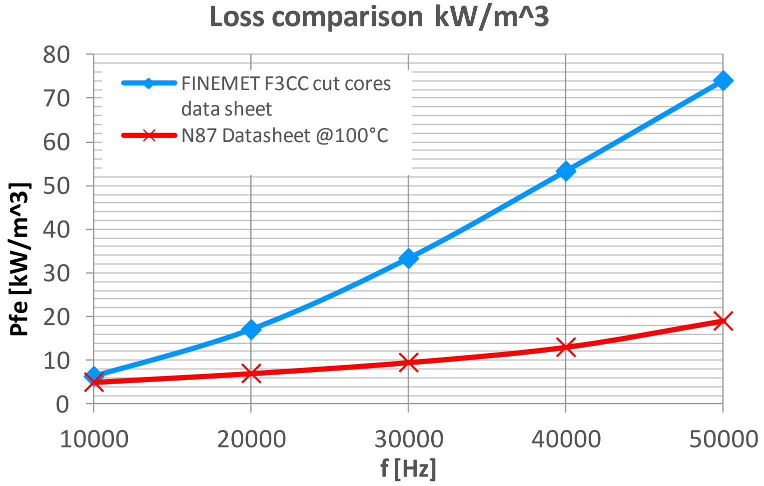
- Interleaving is one of the key measures in the development.

[1] Jürgen Biela, “Wirbelstromverluste in Wicklungen induktiver Bauelemente”, Part of script to lecture Power Electronic Systems 1, ETH Zurich, 2007

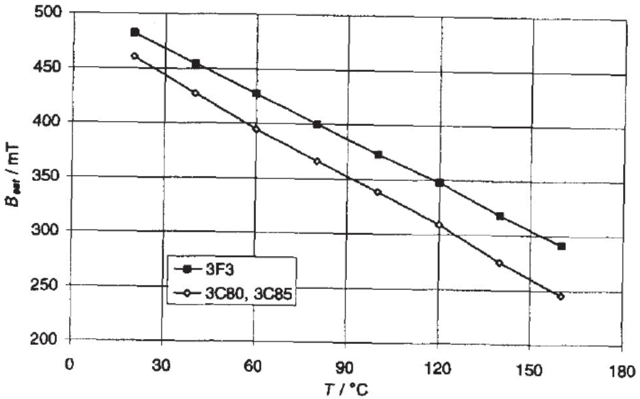
CORE LOSSES

Choosing core material is not distinct.





Although Ferrite offers minimum losses in higher frequency region,
degradation of saturation induction because of temperature reduces loss advantage.



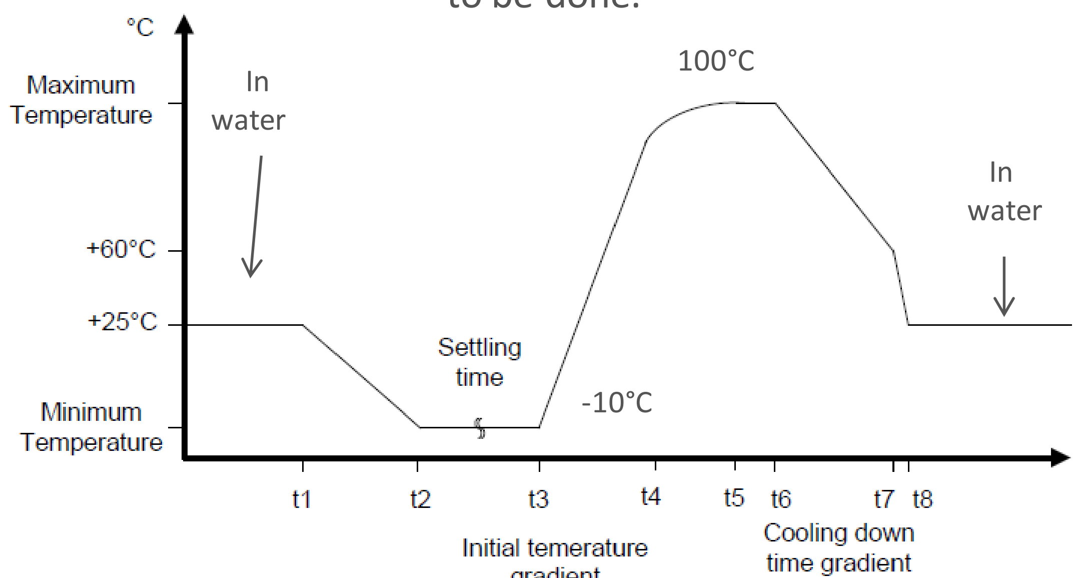
Temperature dependence of saturation flux density [2]

[2] Ansgar Brockmeyer, „Dimensionierungswerkzeug für magnetische Bauelemente in Stromrichteranwendungen“ Aachener Beiträge des ISEA, 1997

ENVIRONMENT

http://bahnbasher.blogspot.de

- mounting in IP20 area (ice, sand, dust, dirt, hard temperature cycles)
- strong mechanical vibrations within usage
- voltages up to 3kV. Power 10kVA-500kVA. Switching frequencies 4kHz-24kHz (and higher are coming up)
- main and stray inductances have to be meet according to the resonant inverter design
- lifetime 30 years. Aging considerations due to environment, vibration and partial discharge have to be done.



STATE OF THE ART DESIGN
CLASSICAL DRY TYPE MF-TRANSFORMERS

MF-TRANSFORMER
CONVENTIONAL DRY TYPE
• up to 200 kVA
@7,2kHz ~2,4kVA/kg

- Dry type transfomer
- High isolation efforts to encapsulate transformer from ice, sand, dust etc.
- Direct cooling
- low weight

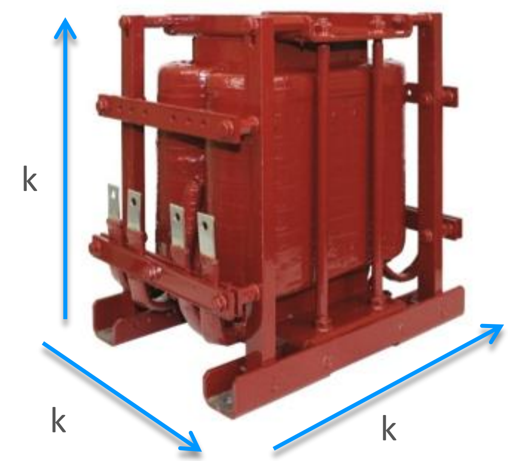
STATE OF THE ART DESIGN
CLASSICAL RESIN POTTED MF-TRANSFORMERS

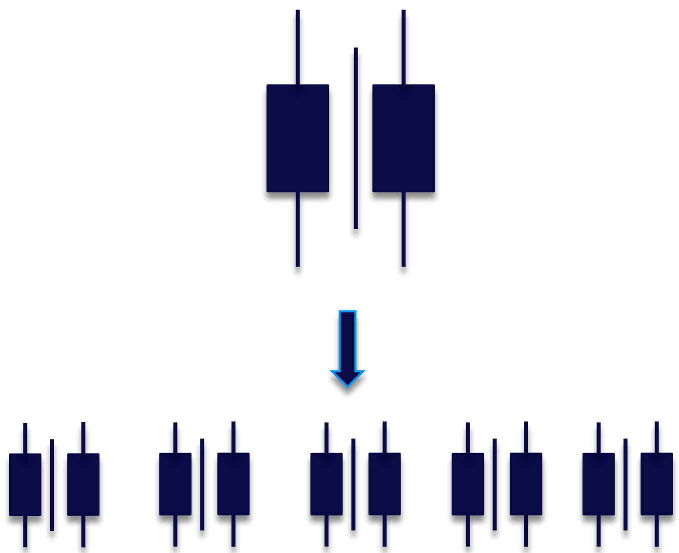
MF-TRANSFOMER
fully potted design
Up to 200kVA
@7,2kHz ~2,0kVA/kg
@18kHz ~2,8kVA/kg

- Fully potted desing
- Standard winding technique is possible
- Simple and easy isolation of transformer because of the resin
- Get rid of the heat is the challange
- Very heavy solution

NEXT GENERATION MF-TRANSFORMER
CASCADED STRUCTURE

- transformer power rises with k^4
- transformer losses rise with k^3
- transformer volume rises with k^3
- transformer surface rises with k^2





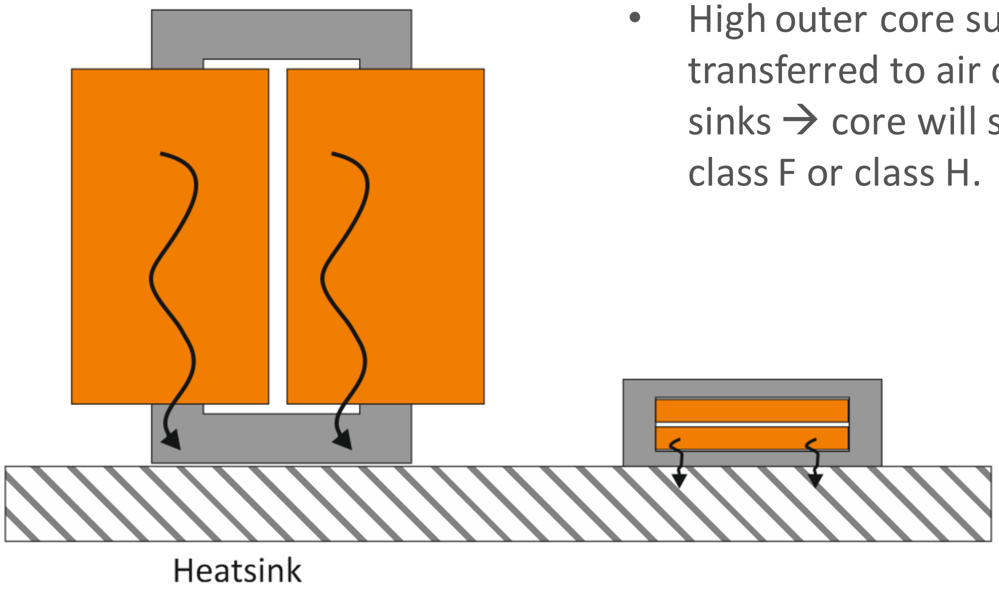
Therefore a cascaded structure is used here. Several smaller transformers can be combined for the desired power.
This design gives the following advantages:

- Smaller currents in each transformer → small HF-litz wires bifilar winded can be used →less copper AC-losses
- Much better ratio between volume and surface → better cooling
- Modular design → bigger production lot size → lower costs→ scalability

NEXT GENERATION MF-TRANSFORMER
PLANAR DESIGN

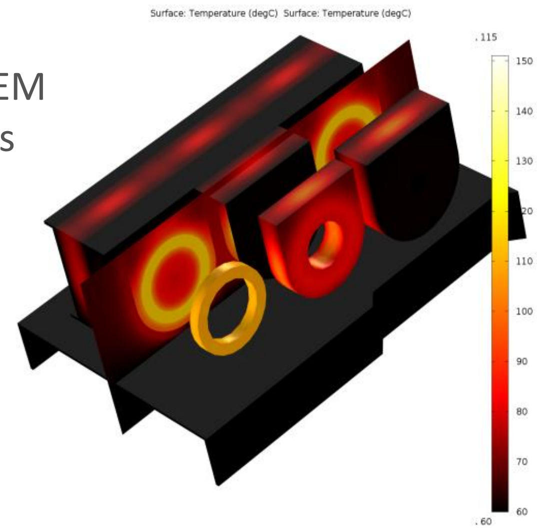
Each single transformer is built as a planar ferrite transformer with special pot core shape optimized for mechanical arrangement in a stack.
Advantages of this core type are:

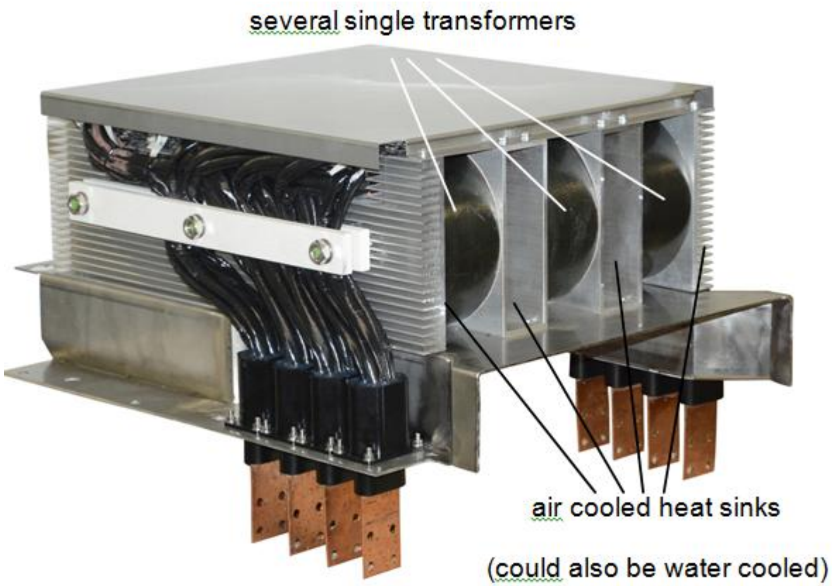
- Easy potting with resin is possible → water resistant design
- High outer core surface area → the heat can be transferred to air cooled or water cooled heat sinks → core will stay cool, even if winding is class F or class H.



NEXT GENERATION MF-TRANSFORMER
OPTIMISED COOLING CONCEPT

Thermal FEM simulations

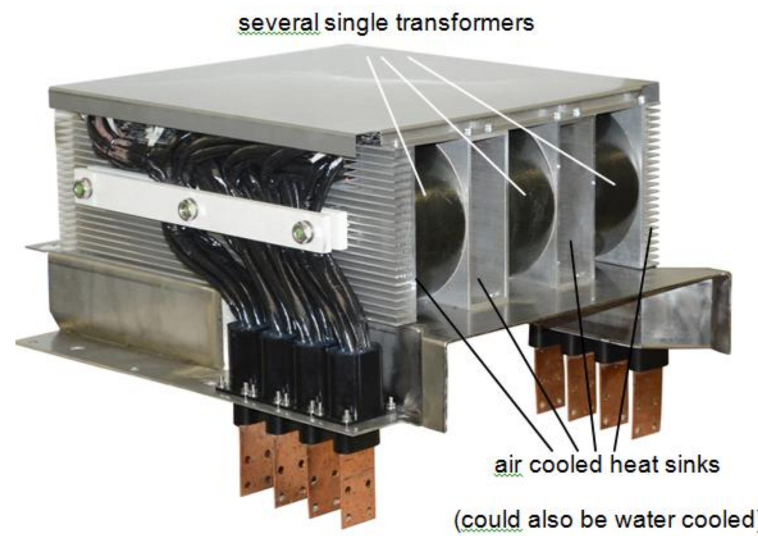




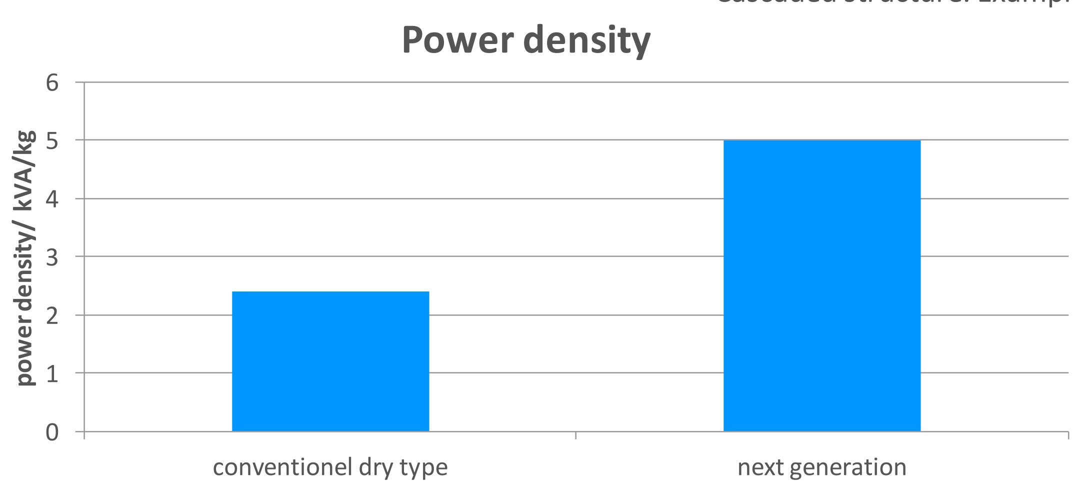
Wind channel tests

NEXT GENERATION MF-TRANSFORMER
COMPARISON

state of the art medium frequency transformer.
Example: 110kVA, 8kHz, 44kg



new generation medium frequency transformer.
Cascaded structure. Example: 250kVA, 24kHz, 50kg



CONCLUSION

- The restrictions of state of the art mf-transformer design considering copper AC-losses, thermal core saturation, cooling possibility and scalability where overcome with the new cascaded pot core structure.
- The power density of the next generation transformer has increased from 2,5kVA/kg (110kVA/8kHz/45kg) to 5kVA/kg (250kVA/24kHz/50kg) for forced air cooling.
- With water cooling, the power density could have even been increased to 6-7kVA/kg.

VIELEN DANK!

THANK YOU!

HABEN SIE FRAGEN?

DO YOU HAVE QUESTIONS?

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