Paris Session 2022

Short Circuit Testing and/or Simulation?

SC A2 – PS3 – Q3.8

Considering the technical difficulties to apply short-circuit testing, but also manufacturing tolerances and unknown parameters of the transformer design and materials, is it possible to rely only on numerical simulation to assess the short-cicuit withstand ability?

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SIEMENS energy

SC Testing and/or Simulation

Current Situation in proof of Short-circuit Withstand Capability

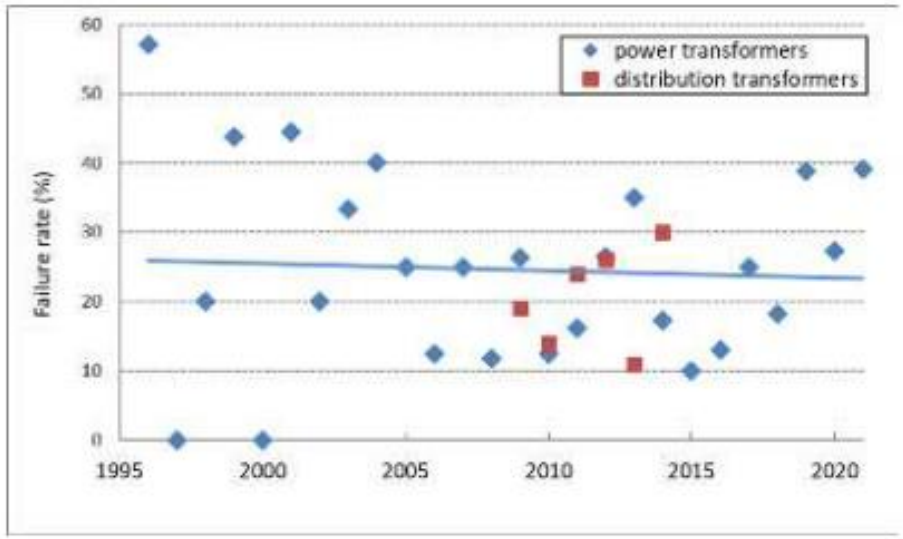


Figure 2 - Test-failure rates of distribution- and power transformers 1993 - 2021

Source: Electra No 323 Aug 2022

SC Testing is applied only in rare cases (special test)

Theoretical design check of stresses in actual Tx against manufacturers design rules or against stresses in a similar SC-tested Tx acc. IEC 60076-5 Annex A

Difficulties to find similar large power transformer (LPT) as a reference Tx

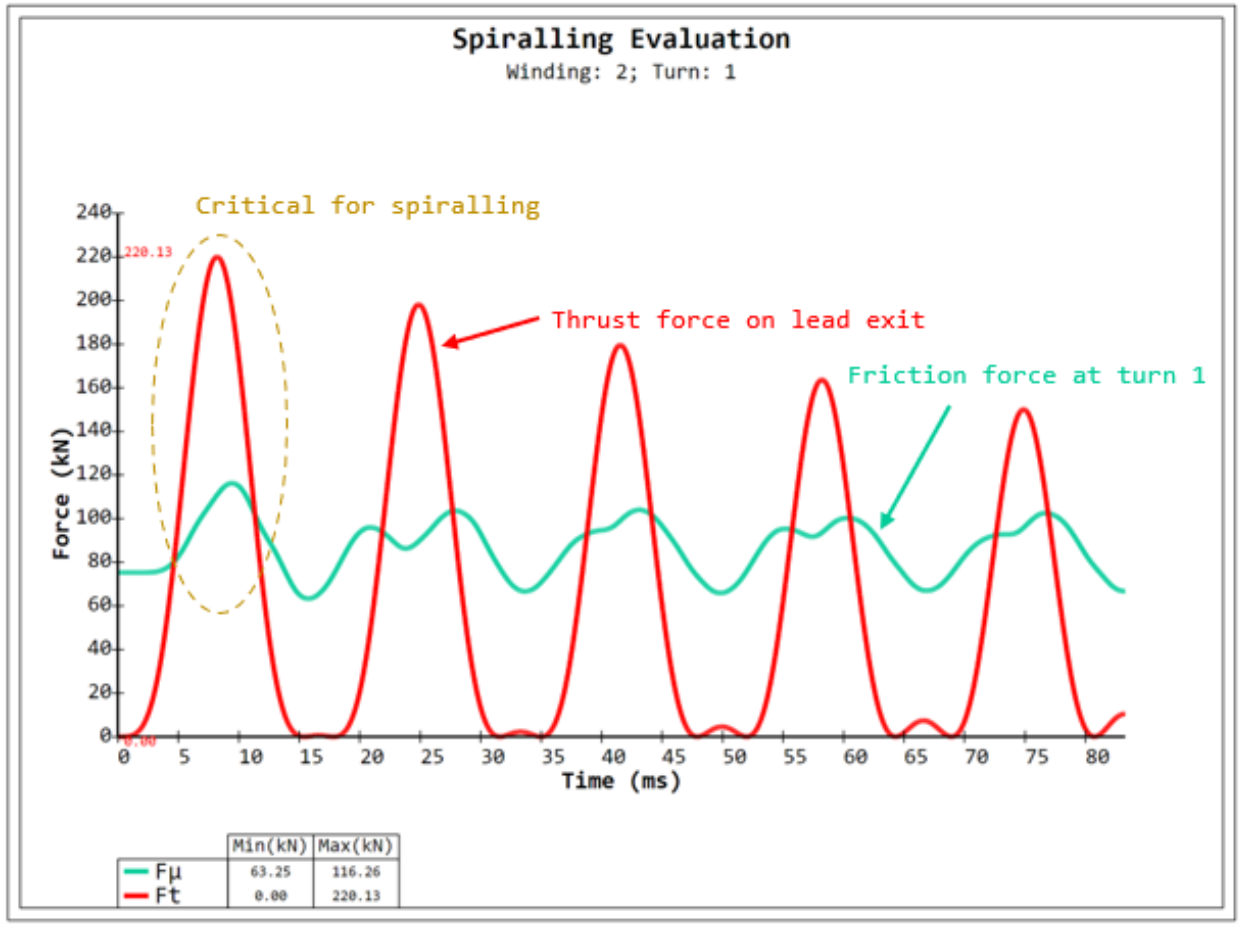
In future compromises allowed in use of multiple similar references and even (partial) model test results to evaluate stresses in an actual design

Failure rate at SC tests of Large Power Tx still high compared to in-service failure rate (~25% vs. ~0,5%)

Modern simulation tools in combination with SC withstand testing of real Tx, models and materials may improve the situation and reduce failure rate in future

SC Testing and/or Simulation

Where can Simulations improve the Withstand Capability and reduce Failure Risks?



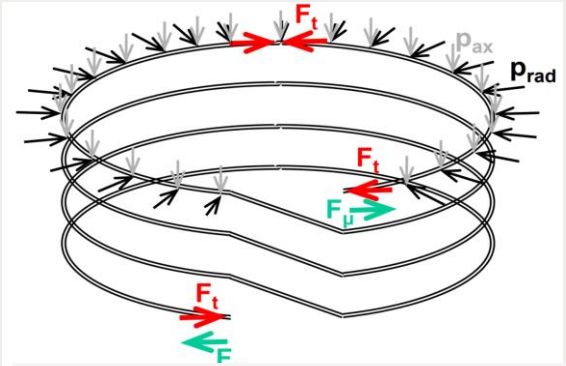
Tangential thrust force and friction force at first winding exit turn

Radial winding buckling failure are rare in LPT but spiraling, axial support and leads failure have higher rates

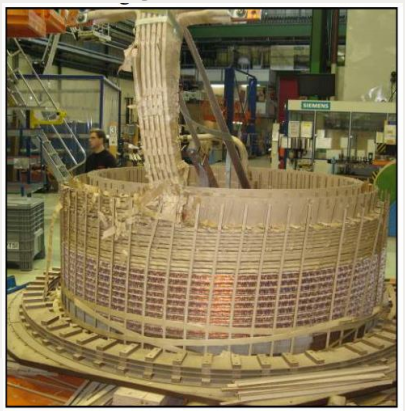
Axial winding and clamping forces as well as bounce-back forces vary in magnitude and waveshape from pure electromagnetic (static) forces

Spiraling is a common failure mode in LPT LV windings and regulating layer windings located in main stray gap

Spring-mass nonlinear system models shall be used to calulate axial winding and thrust forces towards yoke as well as turn friction forces dynamically



Spiraling in a helical winding



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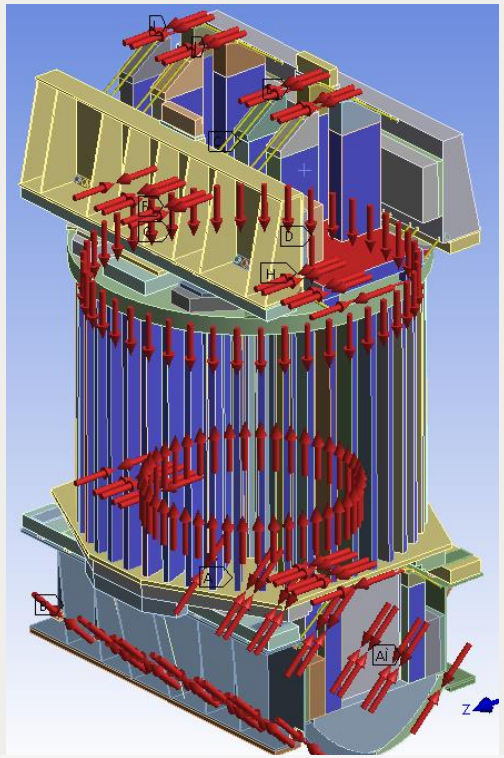
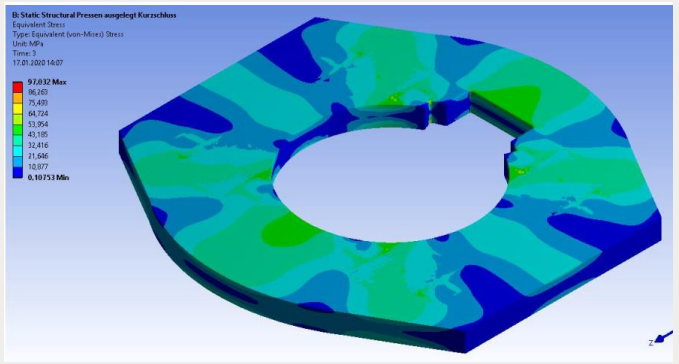
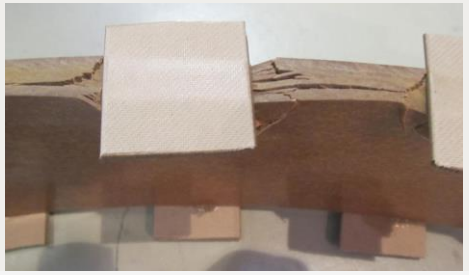
Further examples: Simulation models combined with full-scale SC tests, mock-up as well as materials testing improve design rules and reduce failure risks



Full FEM3D clamping model with clamprings, tie plates and windings to apply SC thrust forces



Von mises stress in clamping ring under short-circuit thrust forces



Material test on end-support ring

Transient non-linear spring-mass models [1)] also useful in daily design to calculate dynamic axial thrust forces and to avoid end-insulation collapse and clamping ring damages

3D-FEM methods can be used for structural studies but not practicable for design verification in daily work
Simplified component models can reduce design effort

Conclusion

From time to time full-scale SC testing and
-evaluation of LPT units in the field
-combined with material and mock-up testing
is essential to **empirically** tune manufacturer´s simulation models and establish critical stress limits

Numerical simulation is only reliable with experimental validations and empirical tuning!

[1)] Koczka, G.; Leber, G., "Empirical Damping of Non-Linear Spring-Mass Systems," in IGTE Symposium, Graz, 2020.