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SmartCoil –Shielded Core Reactor for Current Limitation on the Distribution Level

A. Kudymow[1], C. Schacherer[2], A. Bauer[2], H.P. Krämer[2], S. Elschner[1,3], J. Brand[1], S. Strauss[1], V. Zermeno[1], W. Goldacker[1]

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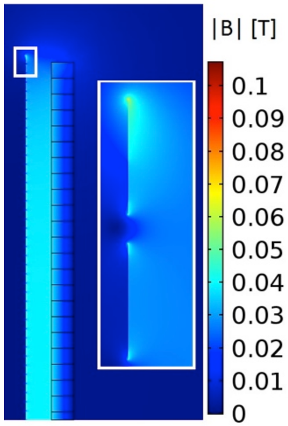
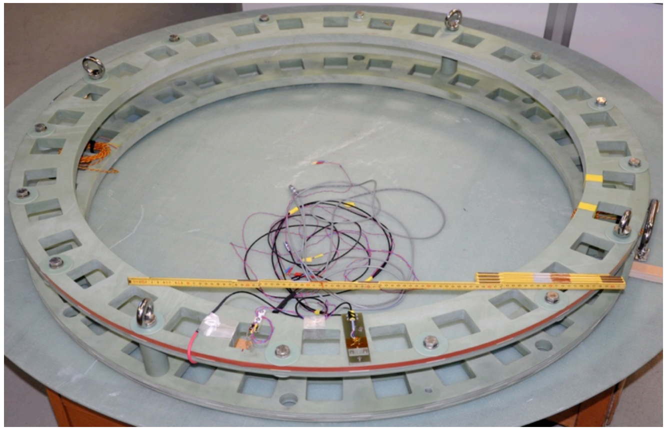
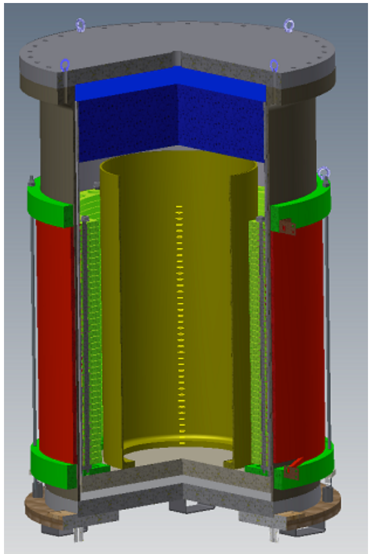
[1] Karlsruhe Institute for Technology KIT, Institute for Technical Physics, [2] Siemens AG CT Erlangen, [3] University of Applied Science Mannheim







Project profile

Short description

- Design, construction und presentation of a novel nonlinear reactor coil for the fault current limiting
(10 kV / 600 A single-phase)
- The concept uses a stack of superconducting shielding rings to reduce the impedance of the reacor during normal operation

Bundesministerium
für Wirtschaft
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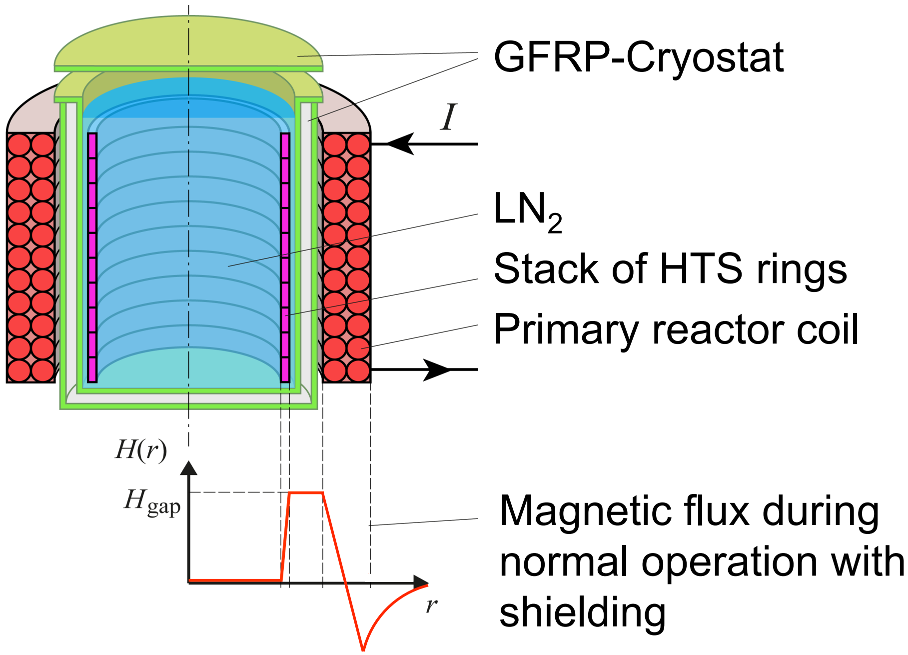
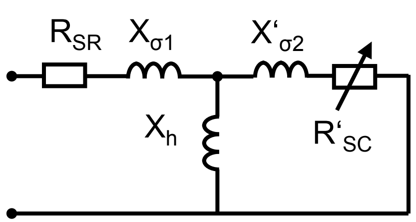
Profile

- Project period: 09/2014 – 02/2018
- Funding: German Government, Federal Ministry for Economic Affairs and Energy (Grant 03ET7525A)
- Project partners:
  - Karlsruhe Institute for Technology (KIT)
  - Siemens AG

Project concept and specification





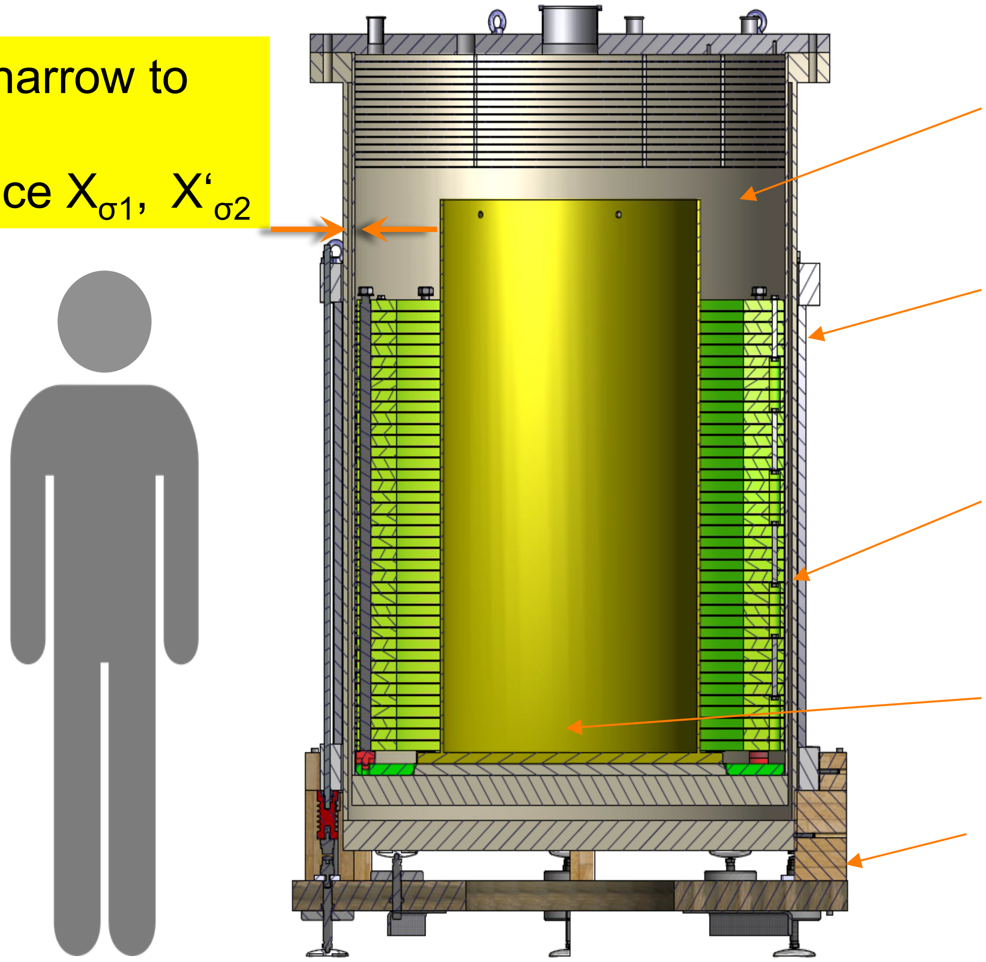
- Specification of **Smart**Coil (single-phase)

Protected power S_{SFCL}	3,46 MVA
Voltage U_{SFCL} (10 kV / √3)	5,774 kV
Rated current I_D	600 A
Frequency f_n	50 Hz
Fault limiting time T_{lim}	≤100 ms
Impedance of reactor coil	6%
Impedance ratio between the limiting- and the nominal operation	**≥ 4**

Gap must be narrow to decrease the stray impedance $X_{\sigma 1}$, $X'_{\sigma 2}$

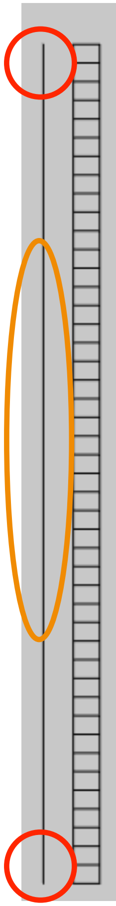
Basic component parts of SmartCoil

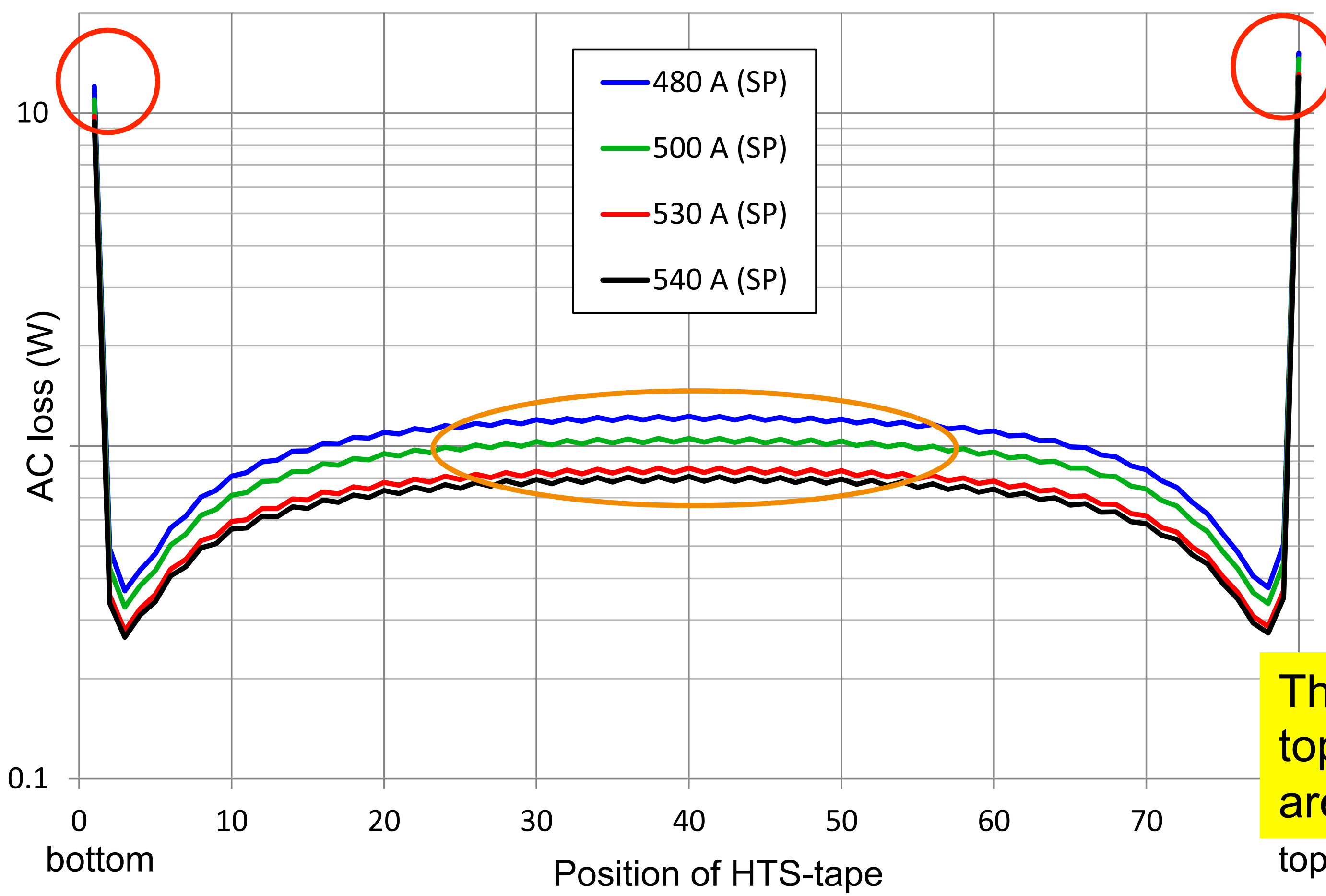
Gap must be narrow to decrease the stray impedance $X_{\sigma 1}$, $X'_{\sigma 2}$

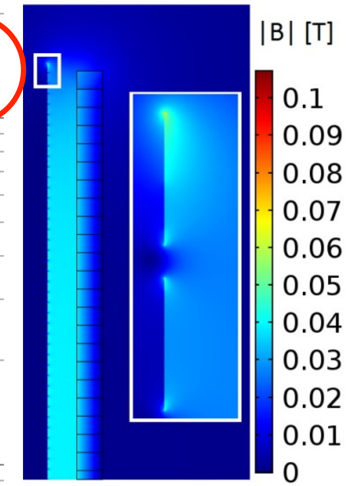


Simulation of AC-losses in HTS nominal operation

- Contribution of the individual HTS-rings to the AC-losses







Simulation of magnetic Field strength

The losses in the top&bottom rings are to reduce

Simulated AC-losses in HTS rings nominal operation

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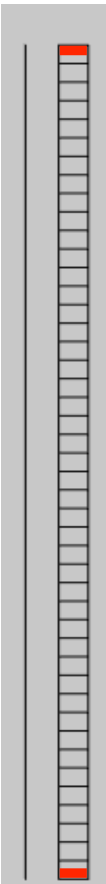
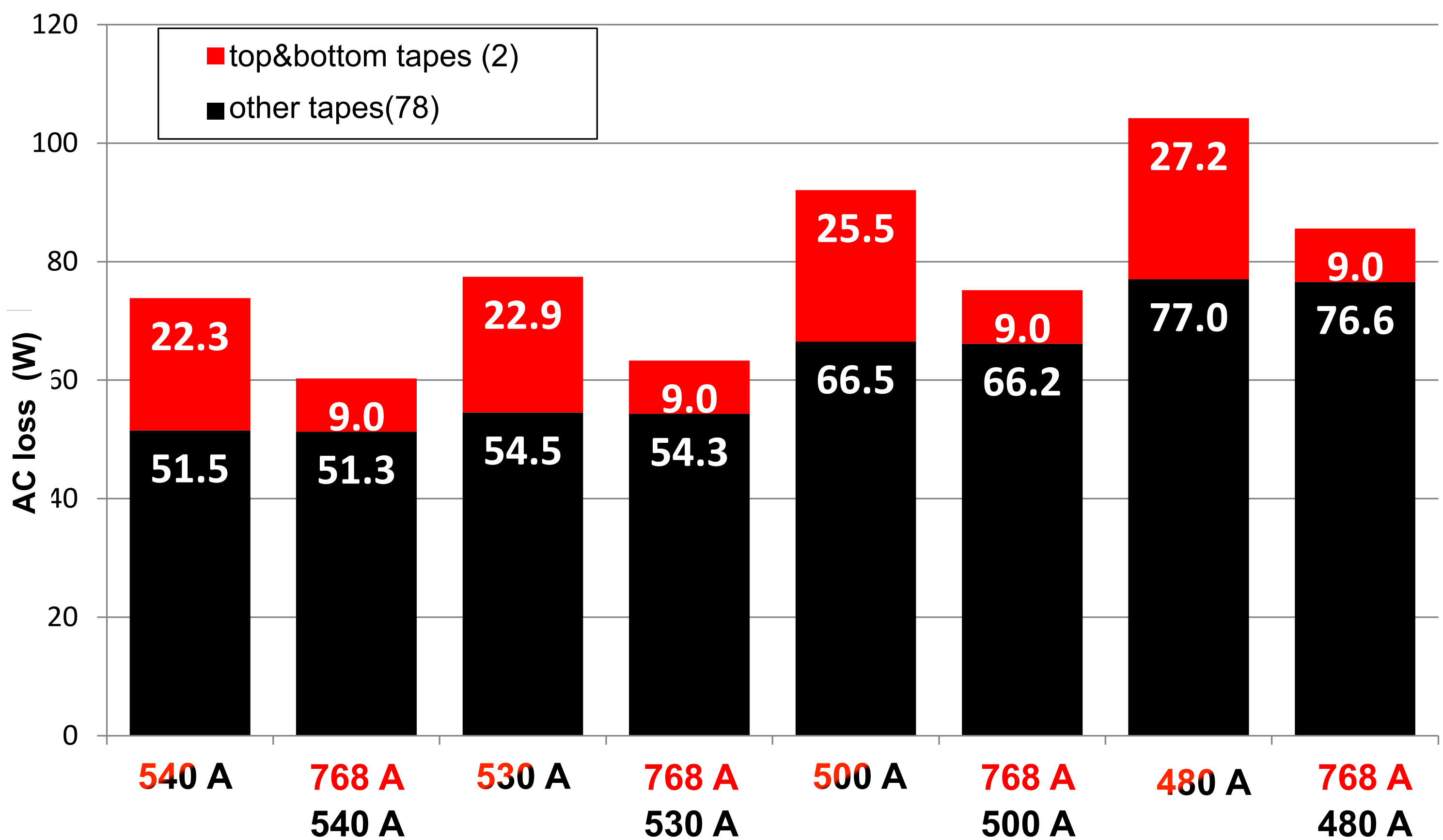
- Contribution of the top&bottom rings to the AC-losses

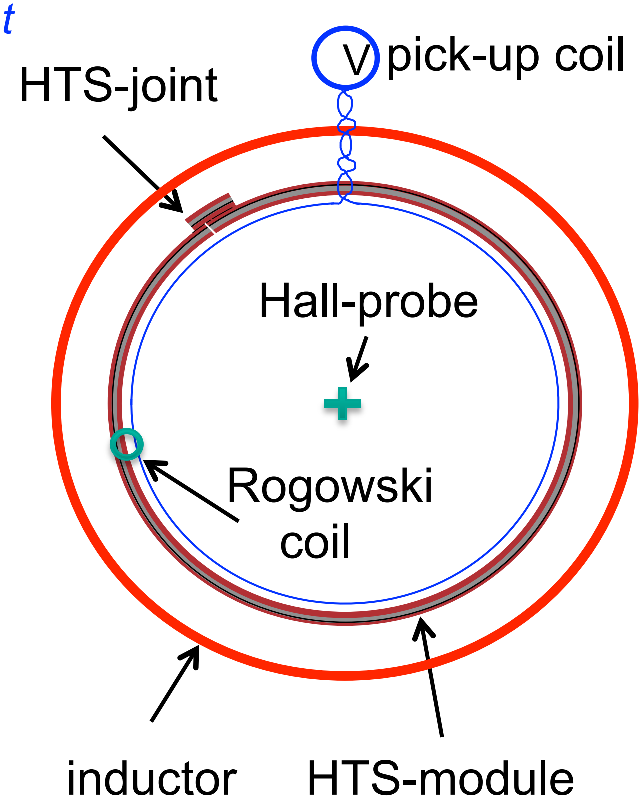




HTS with the higher critical current will be used in the top&bottom rings

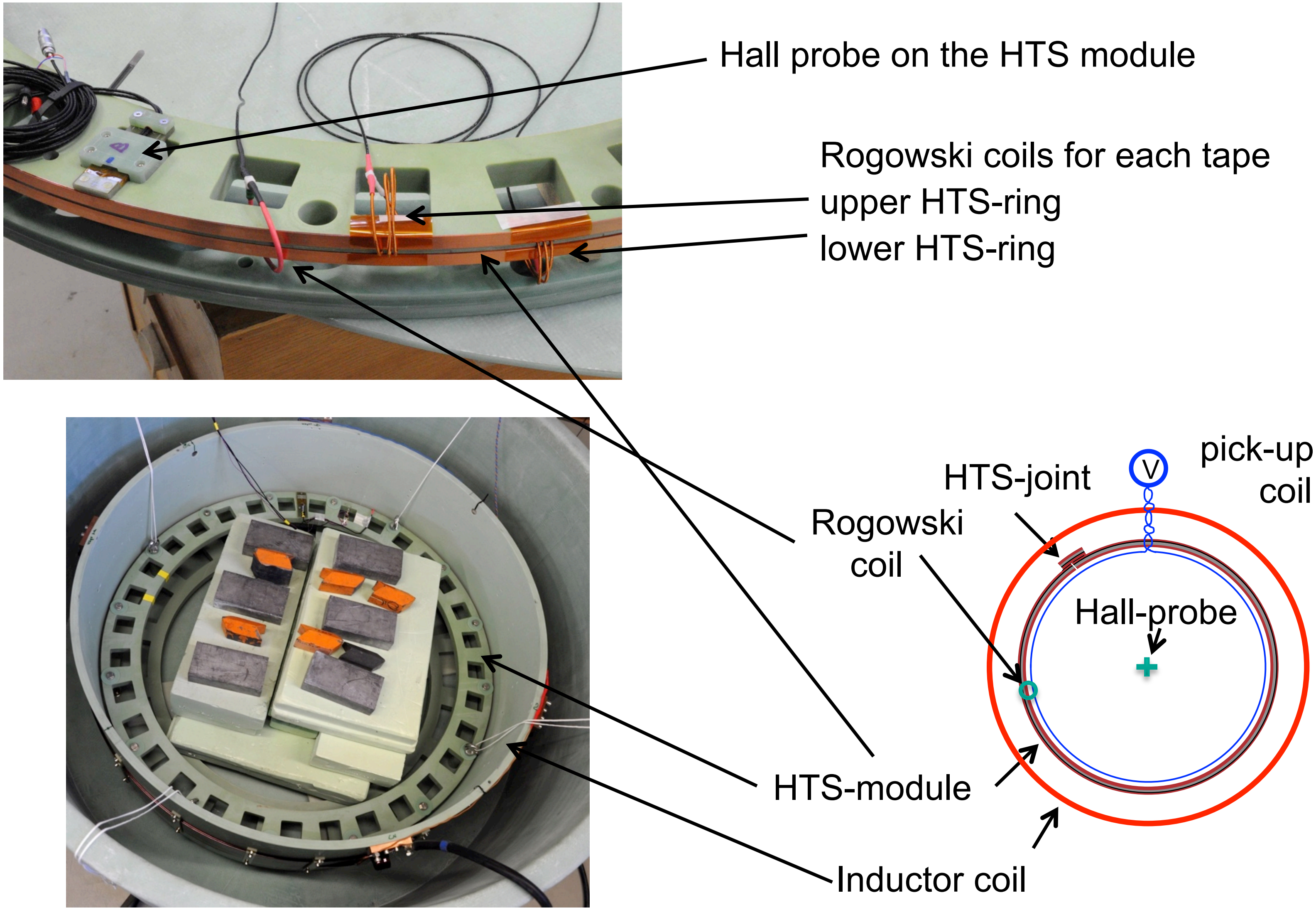
Set-up for component test

- DC-test
  - Measurement of critical current I_C
  - Measurement of contact resistance R_{joint}
  - Conform to specification?
  - Any degradation in test?
- AC-test
  - Quench of HTS
  - Imitation of the fault conditions
  - Thermal cycles



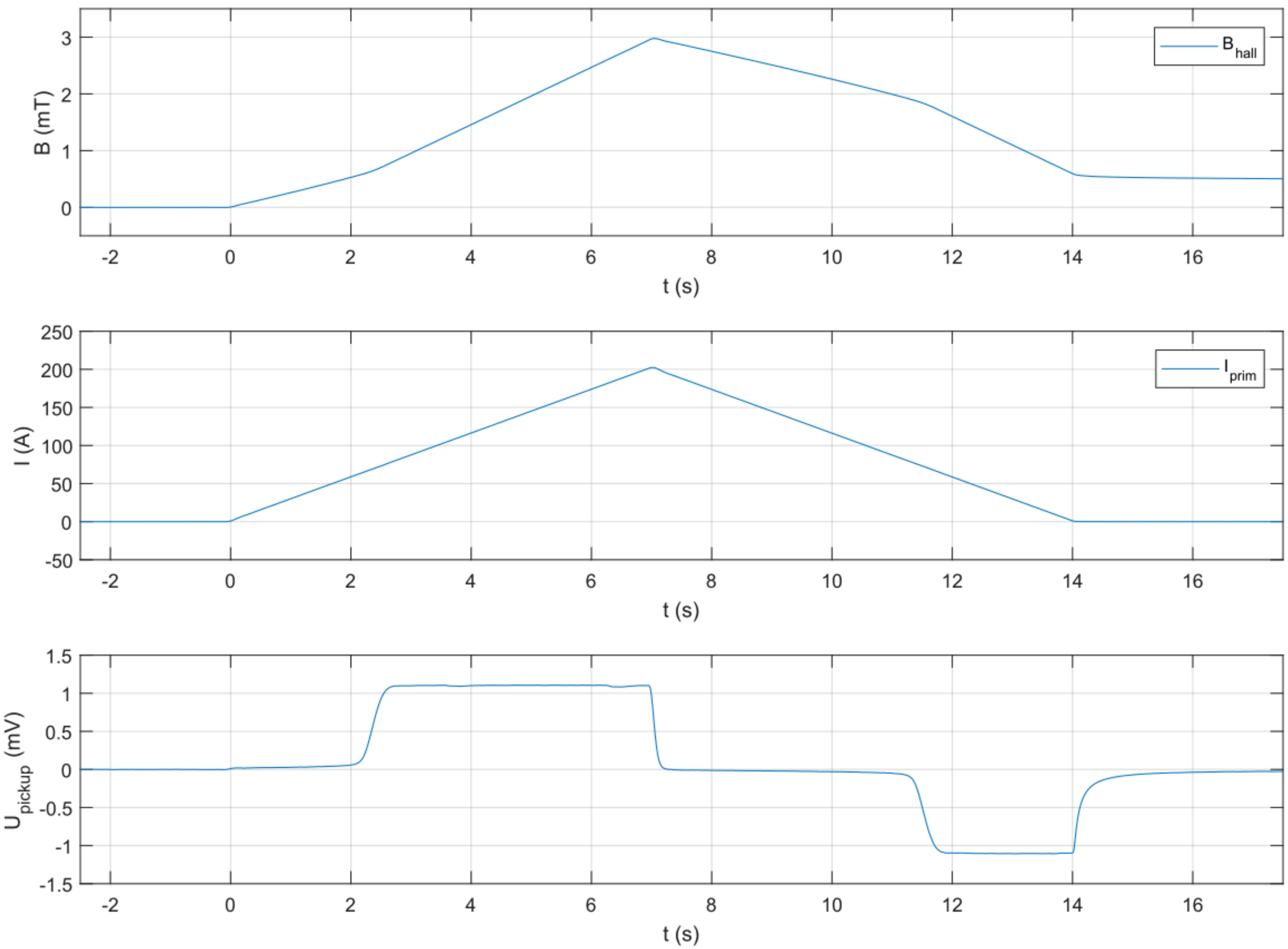
contactless measurement on HTS-ring

Set-up for component test: DC/AC



DC-testing of HTS-module (1 HTS ring)

- Determination of I_C using the inductor and pick-up coils

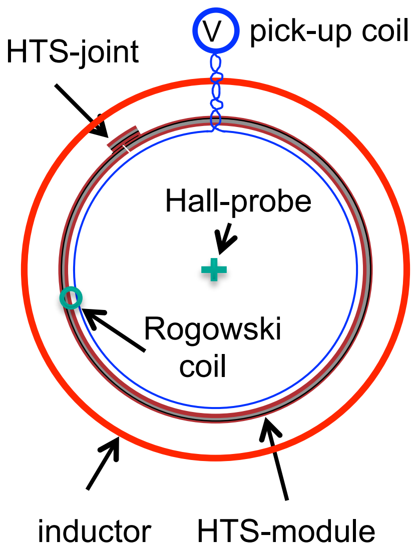


measure:

B_{hall}: central magnetic field

I_{prim}: primary current

U_{pickup}: pickup voltage



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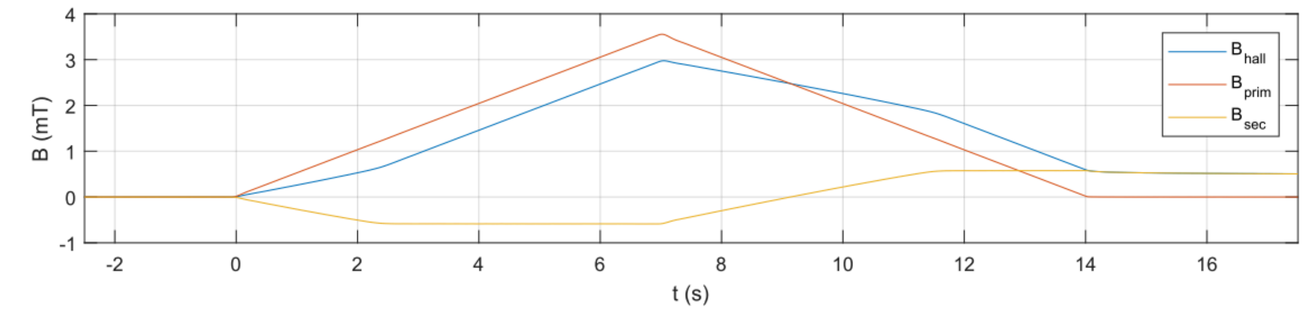
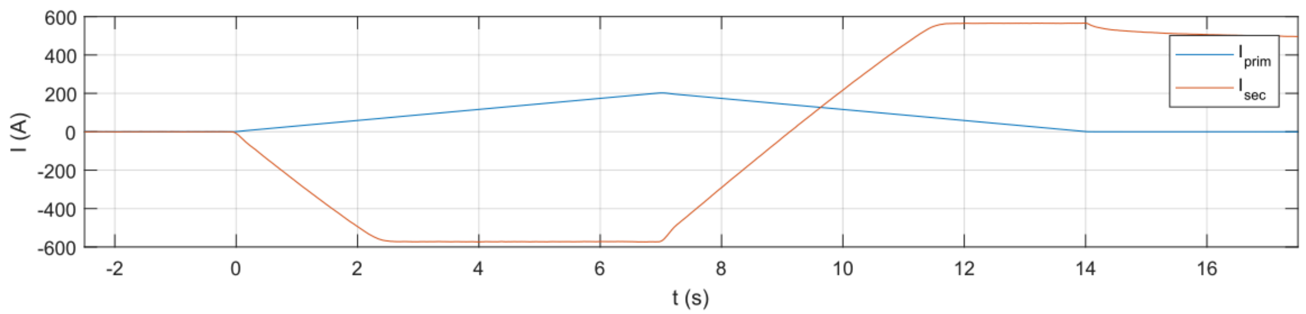
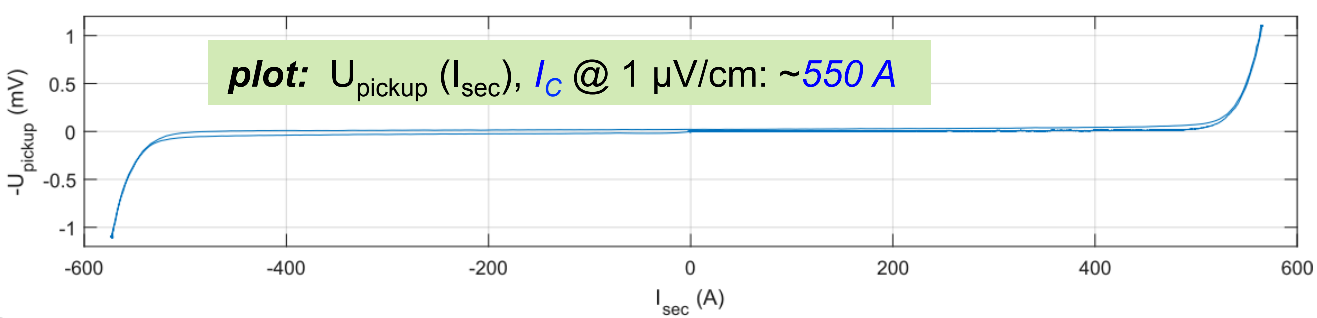




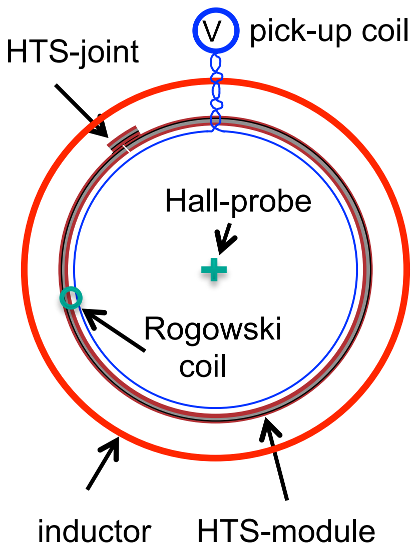


calculate:

B_{prim} = 17.56e-6 T/A * I_{prim}

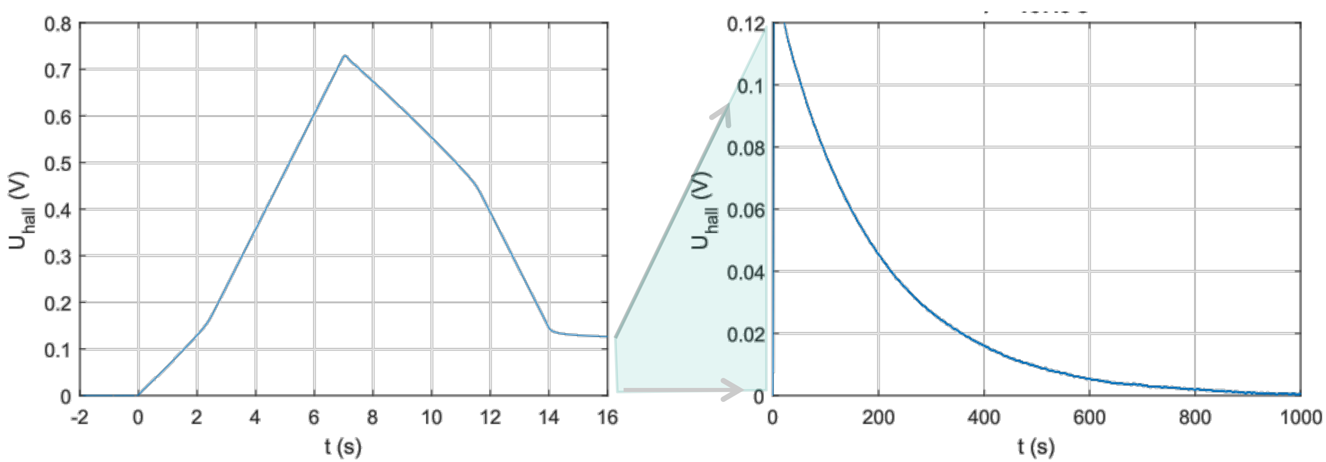
B_{sec} = B_{hall} - B_{prim}

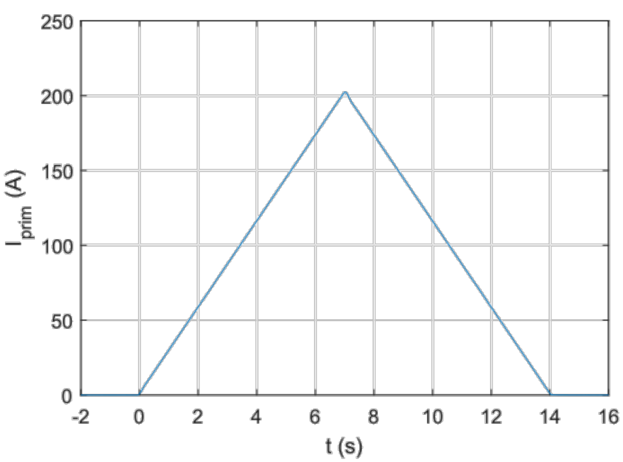
I_{sec} = 0.9807e6 A/T * B_{sec}

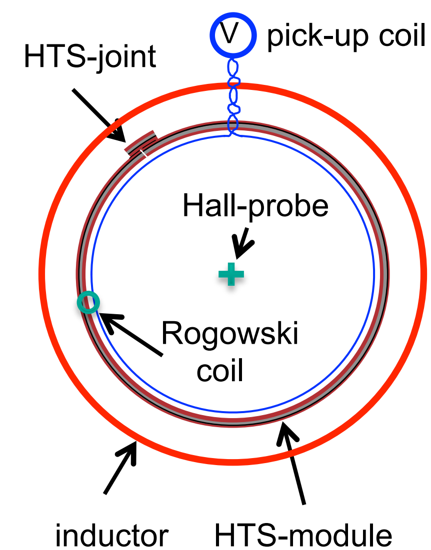


DC-testing of HTS-module (1 HTS ring)

- Determination of R_{joint} using the inductor and the Hall-probe







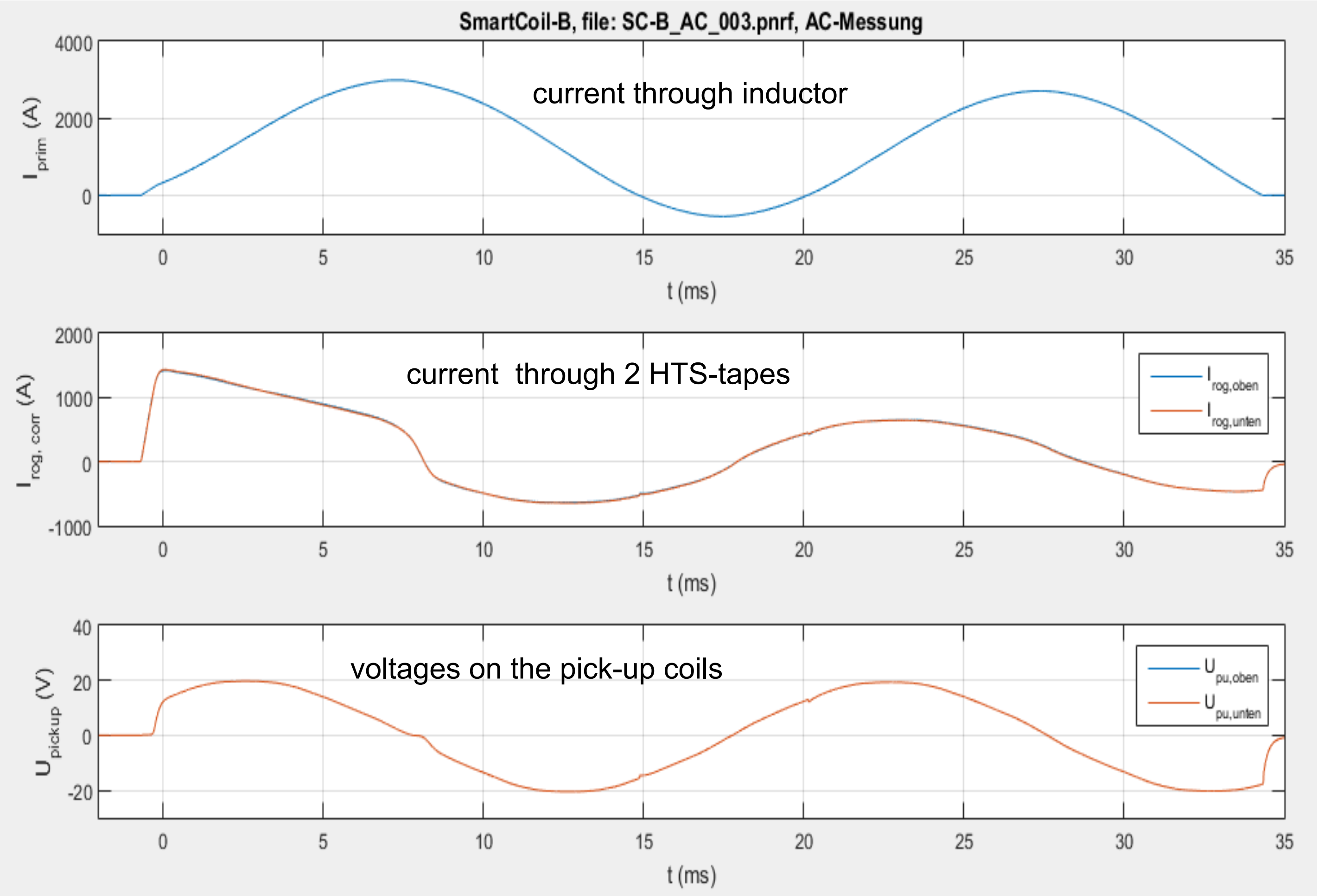
exponential decay of U_{hall} after I_{prim} is back to zero:

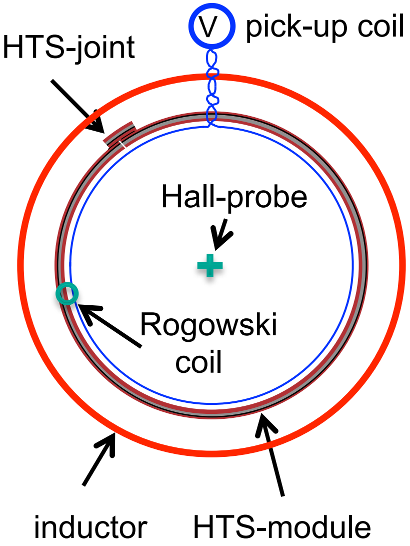
τ = 188 s,

$R_{joint} = L / \tau$ = 4.21 μH / 188 s = 22 nΩ

AC-testing of HTS-module

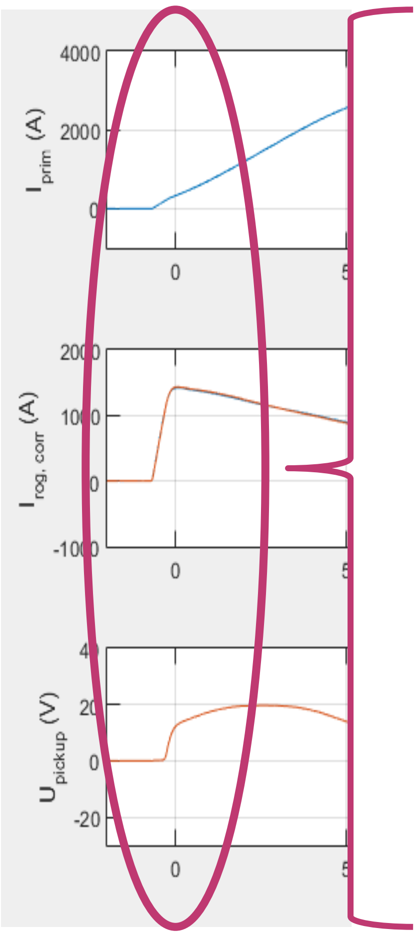
- Quenching transients

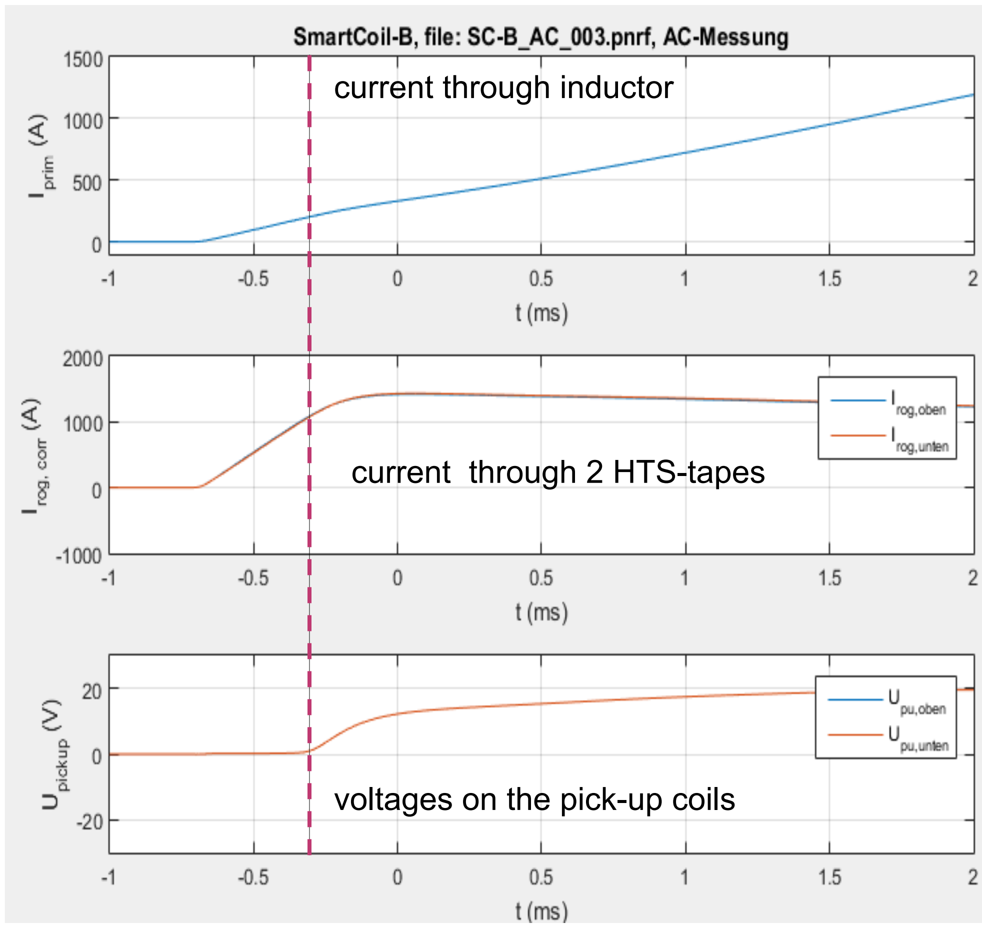


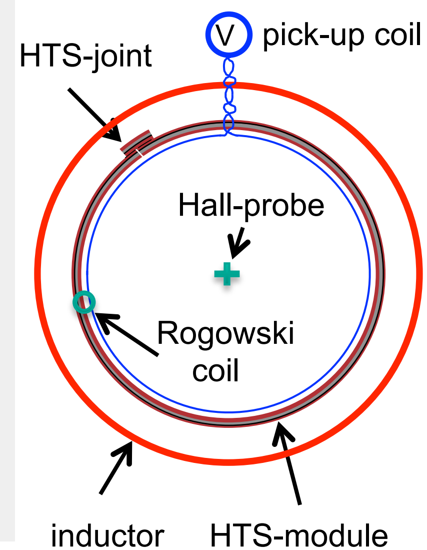


AC-testing of modul

- Quenching transients - zoom in, the time-axis expanded







Summary & outlook

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- **Completed work steps and achieved results**
  - Design of the fault current limiter (single-phase 3,46 MVA)
  - Specification, choice and qualification of 2G HTS
  - Simulations of 2G HTS to optimize the geometry and the losses
  - Specification of the GFRP cryostat with particulary small wall thickness
  - Developing of suitable contacting method for HTS rings (soldering)
  - In-situ determination of critical current and contact resistance
  - 26 (of 40 needed) HTS modules are manufactured and tested

- **Next steps**
  - Delivery of the GFRP cryostat
  - Production and tests of remaining HTS components
  - Installation and performance tests of the entire system in the field
    - Determination of losses in rated operation mode
    - Demonstration of the limiting capacity

Many thanks to the project team and to the companies involved in SmartCoil

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Project (core) team

Anne Bauer (Siemens)
Jörg Brand (Ingenieurbuero Brand)
Otto Batz (Siemens)
Steffen Elschner (KIT, HS Mannheim)
Michael Frank (Siemens)
Wilfried Goldacker (KIT)
Hans-Peter Krämer (Siemens)
Andrej Kudymow (KIT)
Oliver Näckel (KIT)
Marijn Oomen (Siemens)
Christian Schacherer (Siemens)
Severin Strauss (KIT)
Peter van Haßelt (Siemens)
Johann Willms (Synergie)
Viktor Zermeno (KIT)

Companies involved

AMSC
Fabrum Solutions
ILK Dresden (GRP Cryostat)
STI
SuNAM
SuperOx
SuperPower
THEVA
Trench Austria

Add-on reactor coil

Specification of inductor	
Rated current	600 A
Rated voltage (Leiter-Erde)	5.77 kV
Height of inductor	1170 mm
Inner diameter	1318 mm
Number of turns	45
Number of layers	1
Nominal impedance	1.95 mH (0.60 Ω)
Short-circuit voltage	6 % (-> 1.2 %)
Operating temperature	< 155 °C