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AC loss calculations by UTwente for fast-ramp HTS dipole

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AC loss calculations by UTwente for fast-ramp HTS dipole

- October 27th, 2023
  - Hysteresis loss calculation of original magnet design by H. Piekarz -> ~1 kW/m at 5 Hz
- December 11th, 2023
  - Estimation of cooling pipe loss -> smaller than hysteresis loss
- March 13th, 2024
  - Loss reduction by repositioning of conductors -> hysteresis loss 0.2-0.5 kW/m at 5 Hz
  - Alternative design based on UniBo/CERN magnet gave similar values
- May 15th, 2024
  - Ways to reduce power consumption due to AC loss: 1) minimize perpendicular field, 2) use narrow or filamented conductors, 3) increase operating temperature
- June 4th, 2024
  - Higher field calculations: 2.4 T, 3.0 T, 3.6 T -> large loss increase
  - Magnet layout must be adapted: conductor closer to gap, align tapes with the B-field

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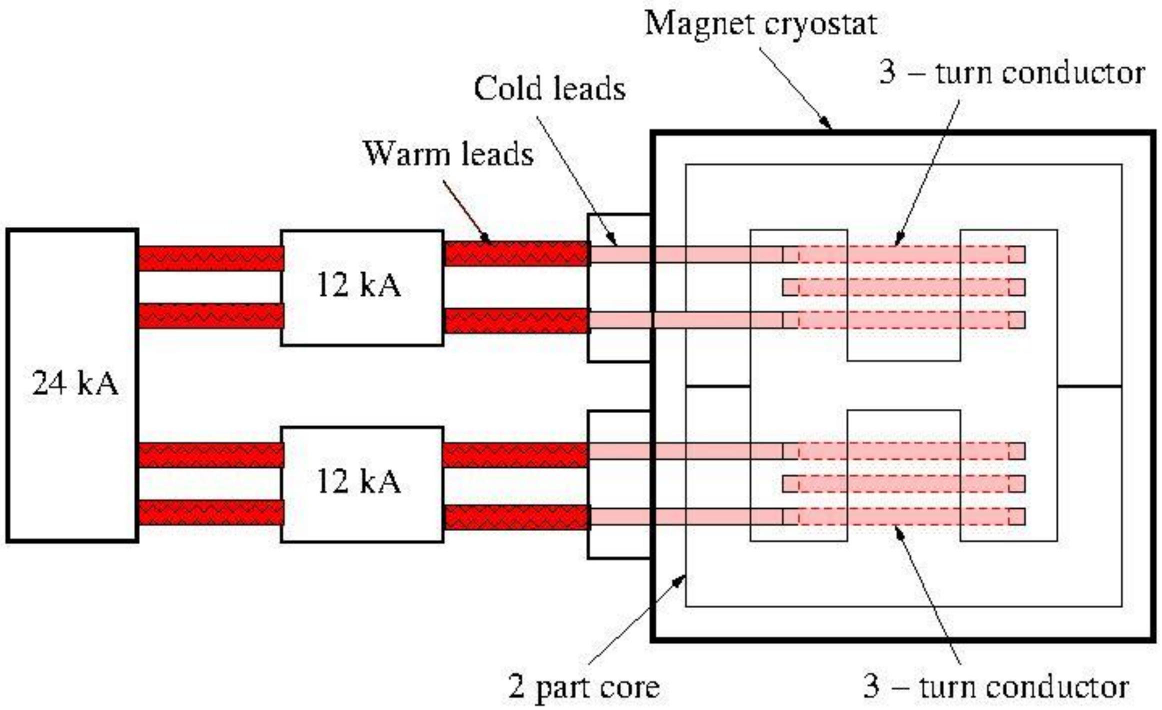
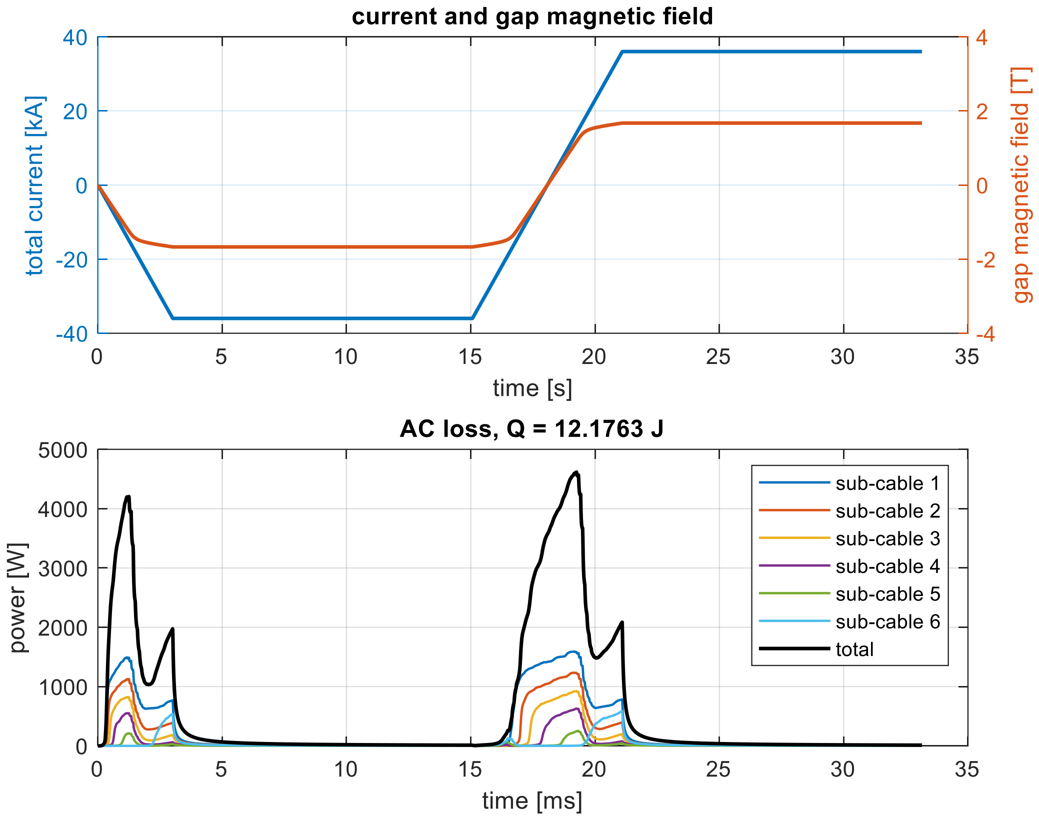
October 27th, 2023: Design by H. Piekarz





- 12 J/m hysteresis loss per quarter magnet per half-cycle
- 96 J/m/cycle hysteresis loss for full magnet -> 480 W/m with 5 Hz repetition rate

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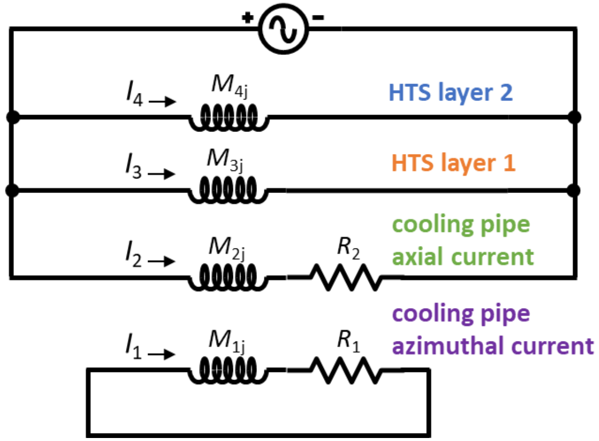
December 11th, 2023

- Cooling pipe loss due to axial field for different cable layouts

Network for cable with a cooling pipe and 2 layers of REBCO tapes
(can be expanded for any no. of layers)



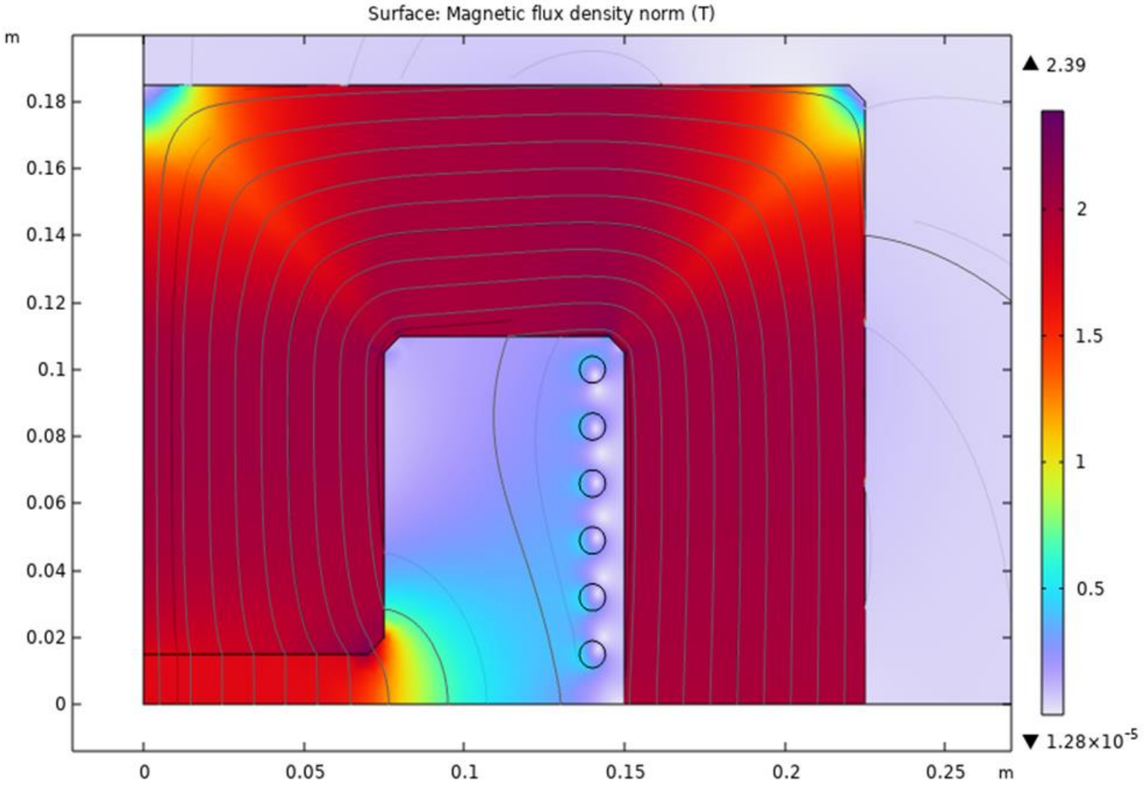
Cooling pipe diameter	Number of HTS layers	Lay angles	Total cooling pipe loss*	Current distribution over HTS layers
16 mm	1	-	30 W/m	Uniform
8 mm	2	Same direction	8 W/m	Non-uniform
8 mm	2	Alternating direction	1.9 W/m	Uniform
4 mm	4	Same direction	3.3 W/m	Non-uniform
4 mm	4	Alternating direction	0.2 W/m	Non-uniform

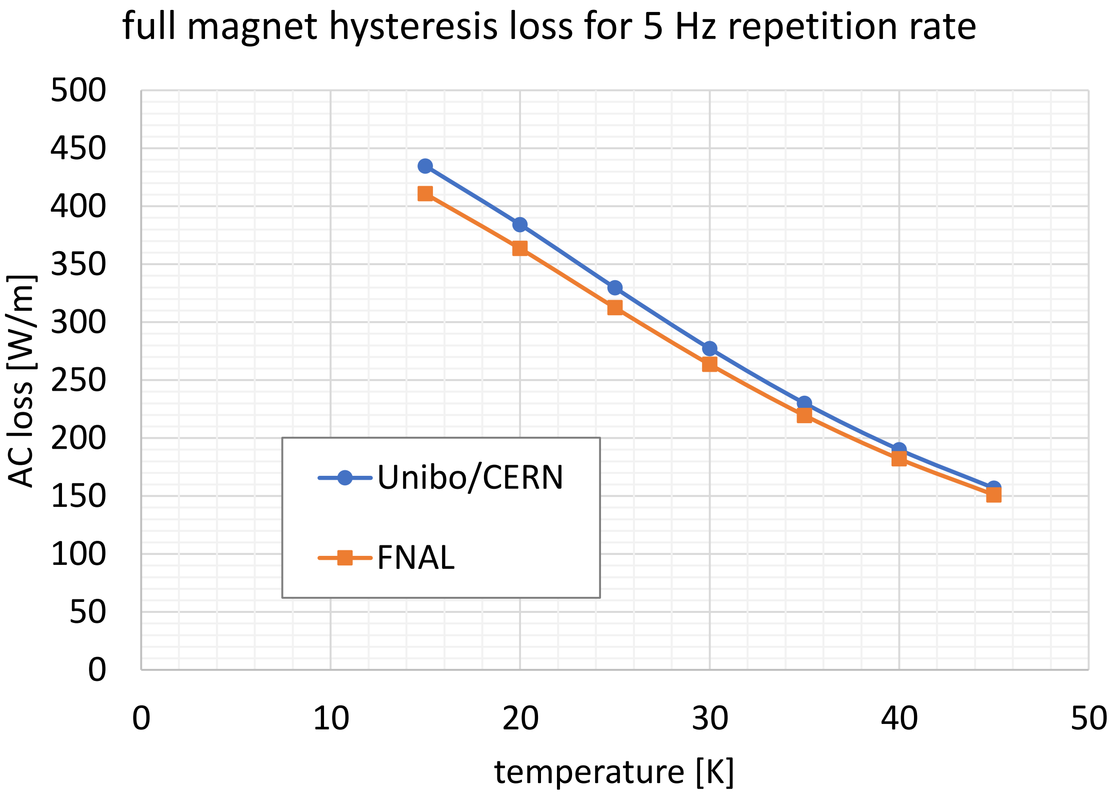
- Round cable with two counter-wound layers of HTS leads to uniform current distribution and low cooling pipe loss

March 13th, 2024

Cable position optimized for minimum perpendicular field in COMSOL.

- $B_{\perp,\mathrm{max}}$ reduced from 0.43 T to 0.19 T

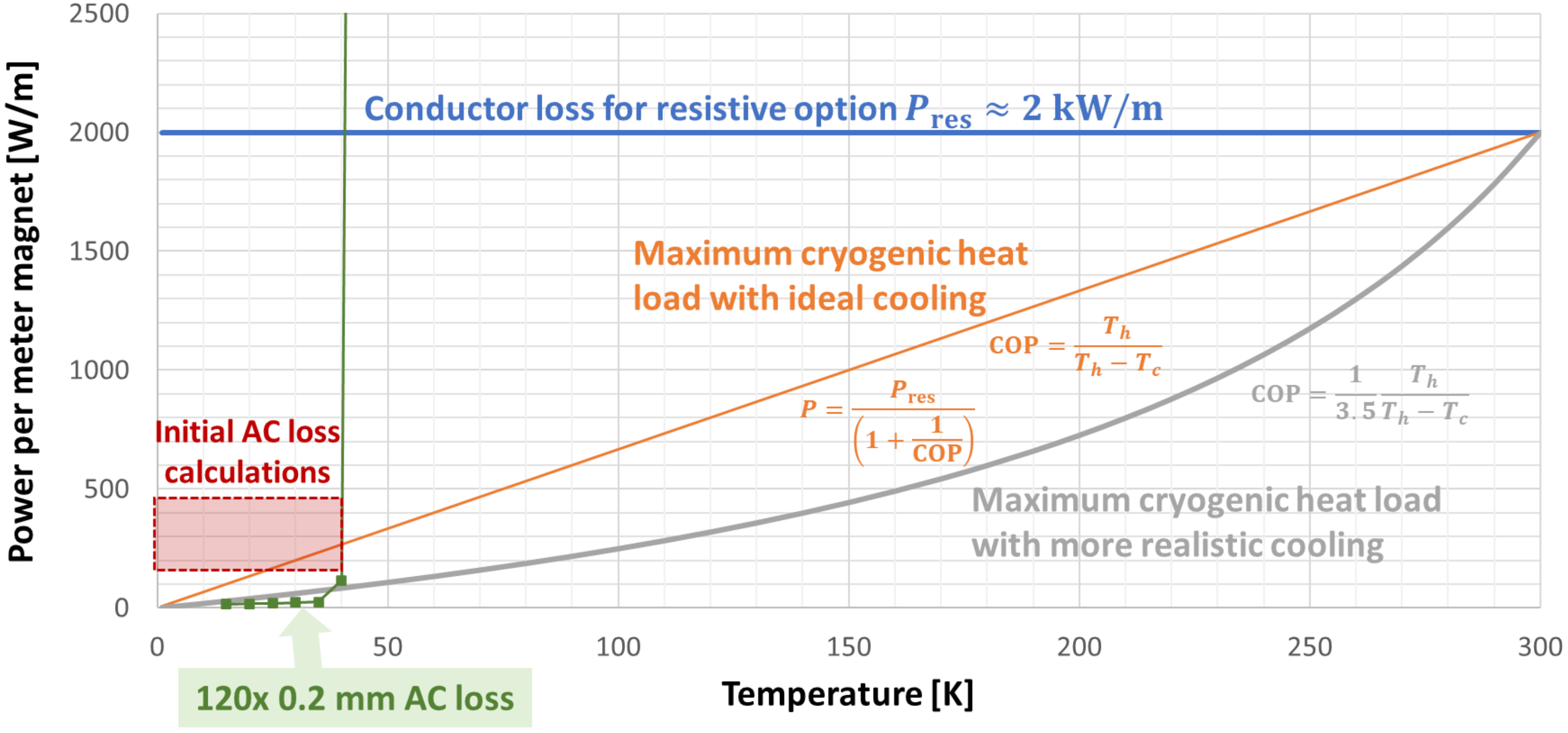




- Reduction of loss to 0.2-0.5 kW/m by changing conductor position

May 15th, 2024

- Theoretical reduction of power by using filamented conductors and increasing operating temperature



- **120x 0.2 mm layout yields AC loss below maximum cryogenic heat load for 15 K < *T* < 35 K !**

June 4th, 2024

- Hysteresis loss calculation for increased gap magnetic field, achieved by increasing current and yoke section.

$I = 36.3$ kA
$B_{gap} = 3.6$ T

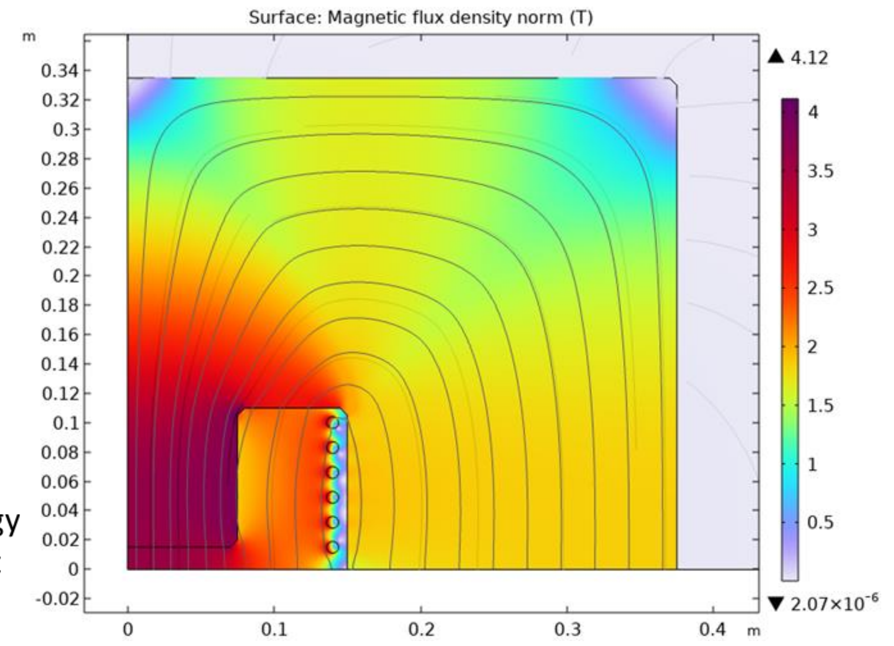
hysteresis loss per cycle

B_{gap} [T]	I [kA]	I_c [kA]	B_{perp} [T]	Q [J/m]	P [W/m]	U [kJ/m]
1.8	5.3	10.5	0.23	21	104	8.1
2.4	13.4	26.7	0.49	110	549	24
3.0	23.8	47.6	0.87	329	1646	61
3.6	36.3	72.6	1.38	716	3578	122

B-field on conductor

x5 Hz

magnetic energy at peak current



- Large loss increase, but design can be optimized by placing conductors closer to the gap and aligning the REBCO layer with the magnetic field

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Discussion points

- How to continue? What magnet designs to be considered? (e.g. aligned block coil of 4-5 T)

- Need for experimental AC loss data at high dB/dt