Design results of a 500 kJ / 200 kW conduction cooled MgB2 SMES magnet

3-LP-LE-I03

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See also 3-LP-LE-S13

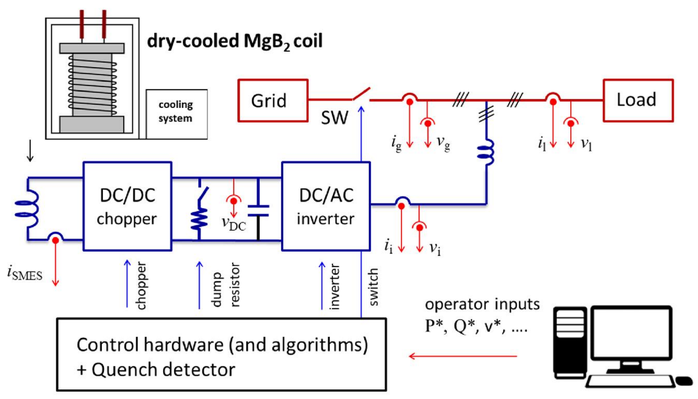
The DRYSMES4GRID project: development of a a 500 kJ / 200 kW SMES system with conduction cooled based on MgB2 SMES

MISE - Italian Ministry of Economic Development

- **Budget: 2.7 M€**
- **Time: June 2017 – June 2020 (+1)**

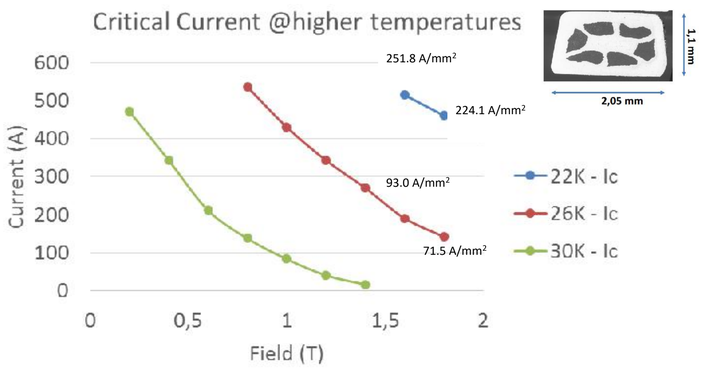
Project Coordinator:
- **Columbus Superconductors SpA, Genova, Italy**

Partners
- **University of Bologna**
- **ICAS - The Italian Consortium for ASC, Frascati (Rome)**
- **RSE S.p.A - Ricerca sul Sistema Energetico, Milan**
- **CNR – SPIN, Genoa**



full system development + testing

Reference Conductor – Rectangular tape with 6 filaments

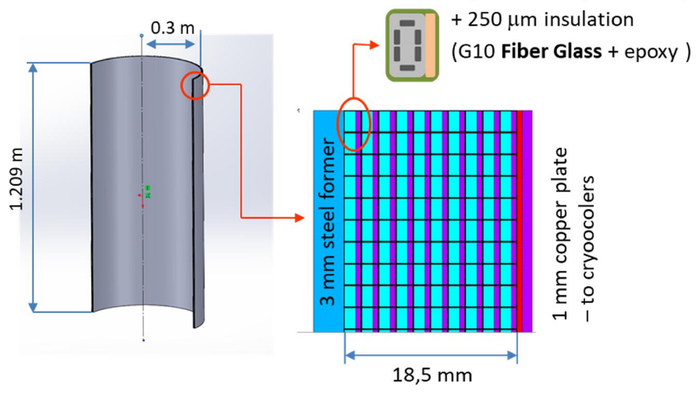


Composition and characteristics	
MgB_2	29 %
Monel 400 (external sheath)	44 %
Nickel 201 (internal matrix)	27 %
Number of filaments	6
Thickness	1.1 mm
Width	2.05 mm
Cross section	2.05 mm²
Twis pitch	600 mm

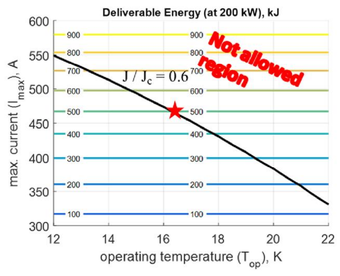
+ 500 μm Cu strip applied at one side by tin-soldering
1+ 25 μm electricla insulating wrapping

Main characteristics of the designed 500 kJ / 200 kW SMES coil

Inner radius, mm	300
Height, mm	1200.6
Number of layers	10
Number of turns per layer	522
Length of cable, km	10.1
Voltage of the dc bus, V	750
Min Current, A	266.6
Max current, A	467
Field on conductor (at Imax), T	1.63
I/Ic ratio (at Imax)	0.6
Inductance, H	6.80
Total eneregy (at Imax), kJ	741
Deliverable energy, kJ	500.4
Dump resistance, Ω	2,14
Max adiabatic hot spot temp., K	95.6



- **The SMES cannot be discharged below I_{min} = 267 A if the power of 200 kW is to be supplied/ absorbed ($I_{min} = P/V_{dc}$)**
- **The designed coil fullfills the specifics (200 kW – 2,5 s) with an operaing temperature T ≤ 16 K and a max. current I_{max} = 467 A**



Material properties data-base

Young's modulus of tape

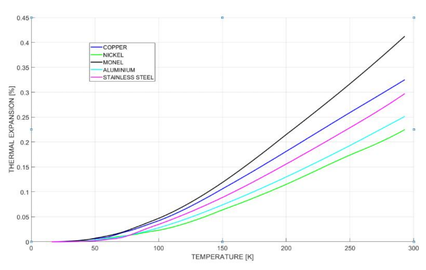
Table 3. Young's modulus of each component of the MgB_2 wire.

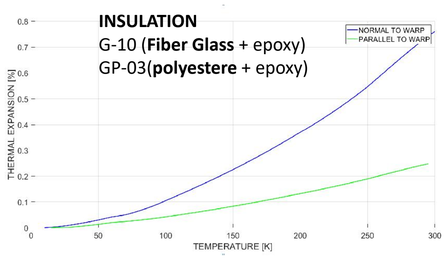
	MgB_2 [6]	Nb-Ni [6]	Monel [21]	Ni [22]	Nb [22]	Cu [22]
E (GPa)	97	230	179	207	103	118

Equivalent Young's modulus of the tape obtained from the weighted average of modulus of components
- Reference tape 157.23 [GPa]
- Aluminium 5083 80 [GPa]
- Stainless steel 180 [Gpa]
- Copper strip (RRR 100) 137 [GPa]
- Fiber Glass G10-CR 35 [GPa]

- K Konstantopoulou, A Ballarino, A Gharib, A Stimac, M Garcia Gonzalez, A T Perez Fontenla and M Sugano, "Electro-mechanical characterization of MgB2 wires for the Superconducting Link Project at CERN"
- EFDA Material Data Compilation for Superconductor Simulation, *P. Bauer, H. Rajainmaki, E. Salpietro*

Thermal expansion coefficients

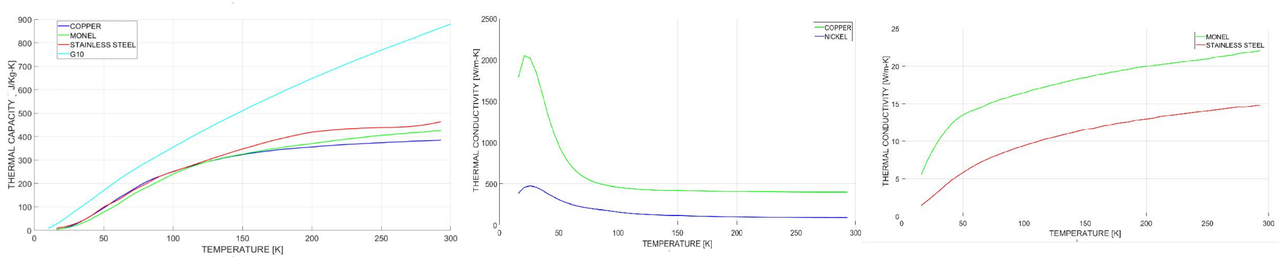




INSULATION
G-10 (**Fiber Glass** + epoxy)
GP-03(**polyestere** + epoxy)

- J. W. Ekin, Experimental Techniques for Low Temperature Measurements, Oxford University Press, Oxford, 2006.
- CRYOCOMP

Thermal capacity and thermal conductivity



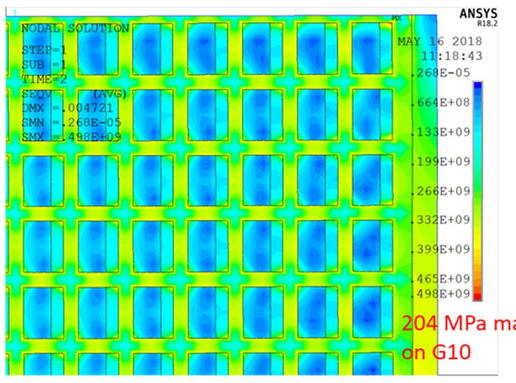
Mechanical Analysis

Mechanical design includes
- **Pretensioning due to winding of the coil**
- **Thermal contraction during cool down**
- **Lorentz force**

Elastic's moduli and thermal expansion coefficients of all materials taken from
- K Konstantopoulou et al., "Electro-mechanical characterization of MgB2 wires for the SC Link Project at CERN", SUST 2016
- J. W. Ekin, Experim. Techniques for Low Temp. Measurements, OUP, 2006
- *P. Bauer et al.*, EFDA Material Data Compilation for Supercond. Simulation
- CRYOCOMP

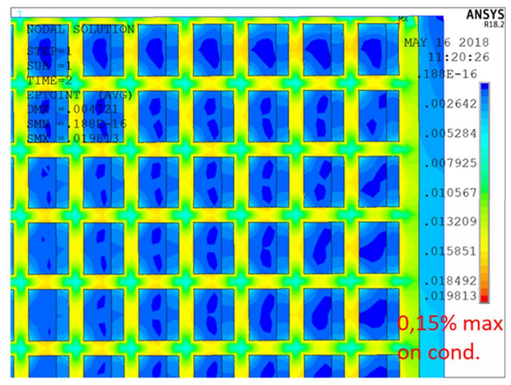
Equivalent Young's modulus of the tape of 157.3 MPa obtained from weighted average

Von Mises stress



Stress within allowable limit for all materials

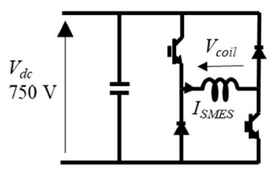
Strain



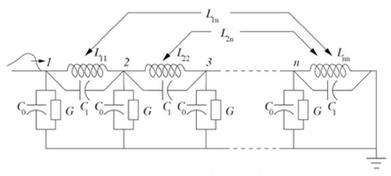
Strain within allowable limit for all materials

Electrical insulation

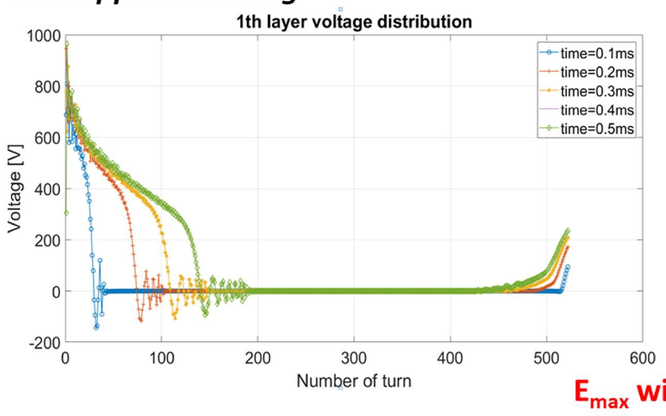
Voltage surge (1 us) on the coil due to switching
Uneven distribution of voltage among turns



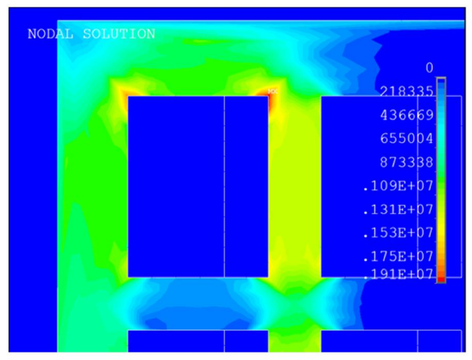
Versus ground voltage distribution of the coil calculated via lumped parameter circuit



Vs. ground voltage of 1st layer's turns at chopper switching



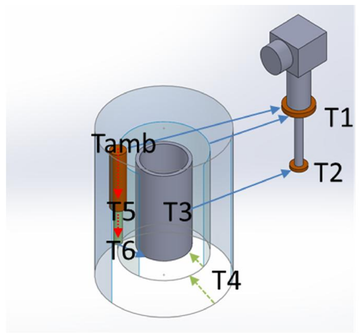
Electric field



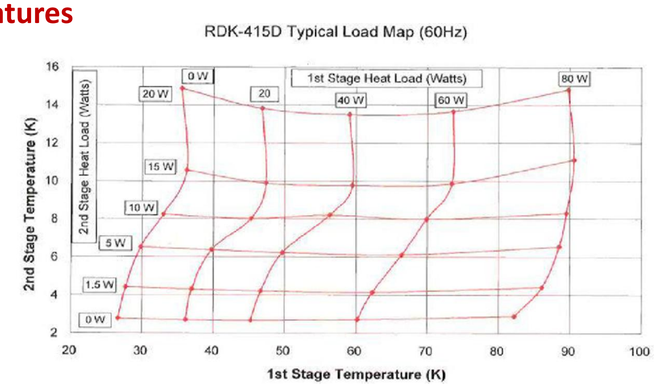
E_{max} within allowable limit of 1.2 kV/mm

Thermal analysis

Steady-state thermal flows and temperatures



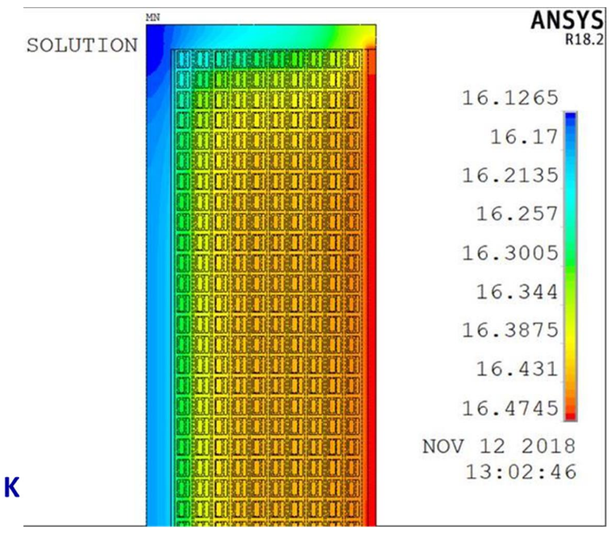
T1 = 114.2 K
T2 = 6.3 K
T3 = 15.9 K
T4 = 154.9 K
T5 = 181.2 K
T6 = 16.0 K
Q1 = 113.0 W
Q2 = 3.2 W



Temperature distribution a the end of one charge/discharge cycle

Inputs
- AC loss power on each turn
- Eddy current power on the copper
- Irradiation power on the external surface
- Conduction power on the insertion points at the top of the magnet
- The drawn power of the cryocooler at the middle point of the cooling layer

Temperature rise of 1 cycle <0,5 K



SEE 3-LP-LE-S13 FOR DETAILS ON AC LOSS AND QUENCH