HTS Workshop at NEDO

IEA HTS TCP ExCo meeting

"Present status of applied HTS in Italy"

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Ricerca sul Sistema Energetico - RSE S.p.A

Italy

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Kawasaki, Japan

Italian SFCL Project – Phase B
(9 kV/15.6 MVA SFCL)

3.4 MVA BSSCO-based SFCL in-field activity is launched

2012

2014

In-field activity successfully completed:
real 3-phase fault limited

Looking for the best architecture of the 15.6 MVA SFCL

2015

2017

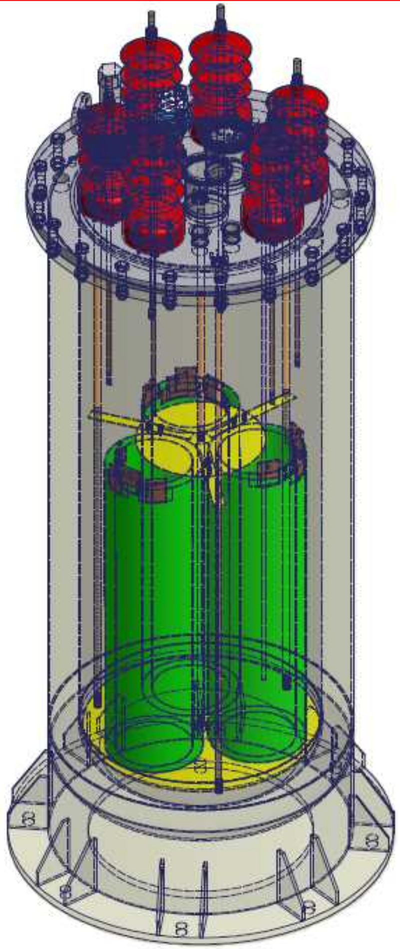
The 2nd generation YBCO tapes feature:

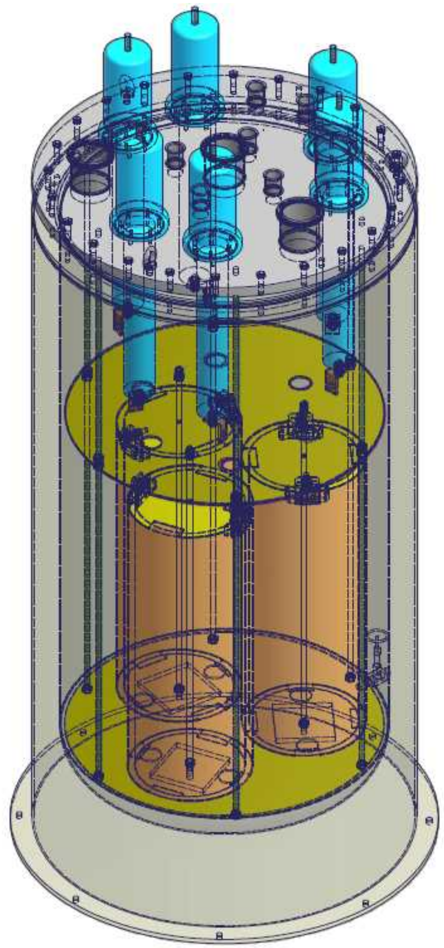
- critical current values up to 2.5 - 3 times higher than BSCCO-tapes
- resistance inserted in the grid after transition is 6-10 times larger than BSCCO tapes
- AC losses for YBCO are 5-10 times lower than for BSCCO at the same current value
- significantly higher unit cost
- major manufacturing difficulties while winding the final coils

a2a Reti Elettriche

RSE Ricerca Sistema Energetico

SFCL Project – Phase A 2009 - 2014		SFCL Project – Phase B 2014 - 2017
9 kV	Rated Voltage	9 kV
250 A	Rated Current	1000 A
12.3 kA	Short-Circuit Current (rms)	12.3 kA
30 kA	Short-Circuit Current (A_p)	30 kA
400 ms	Fault Duration	400 ms
1.7 - 2	Limitation Factor	1.7 - 2
1G BSCCO 2223	HTS tape	2G YBCO CC
1880 m	HTS total lenght	576 m
D = 600 mm H = 1970 mm	Cryostat Overall Dimensions	D = 900 mm H = 2104 mm
77 K	Operating Temperature	65 K





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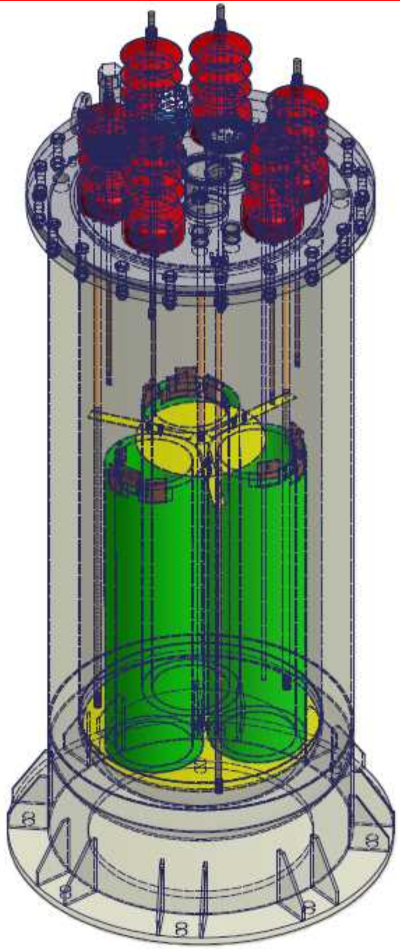
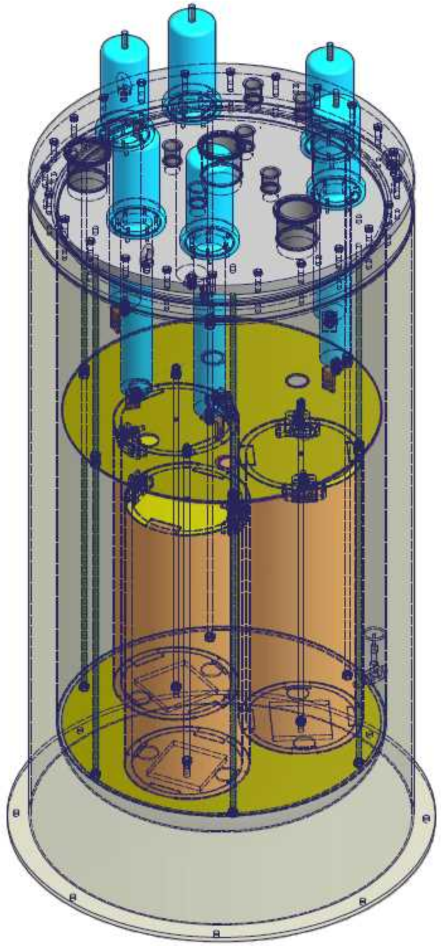




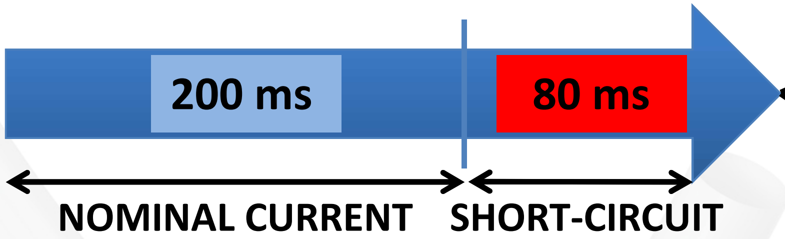
Italian SFCL Project (9 kV/15.6 MVA)
Short-circuit tests

Prototype

- 9 kV/1 kA SFCL single-phase
- No. 2 coaxially-arranged parallel-connected YBCO-based coils anti-inductively wound
- HTS tape total amount of 2 x 96 m

Test general principles

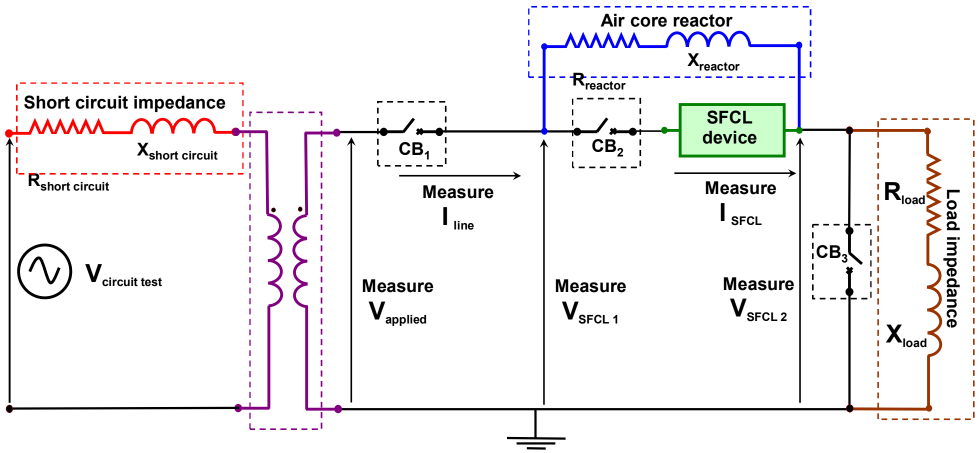
- Test duration: 200 ms nominal current + 80 ms short-circuit
- Test temperature: 65 K
- No. 2 short-circuit current levels tested



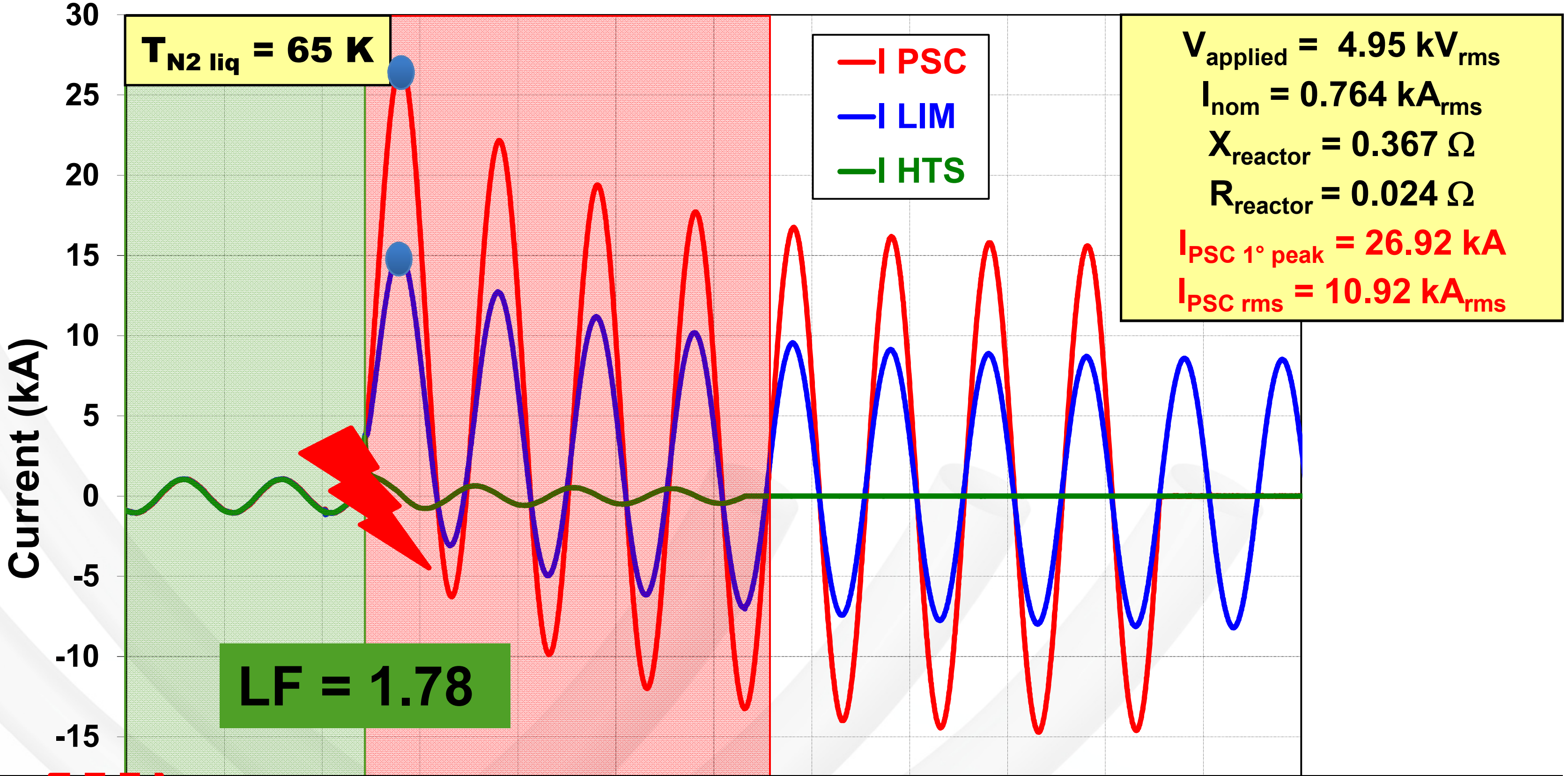
Reduced current test = 6 kA_{rms}

Full current test = 10.6 kA_{rms}

Real implemented parameters	Reduced current test	Full current test
Prosp. current (A_{rms})	6022	10920
Duration (ms)	80	80
Prosp. current 1° peak (A)	15090	26920

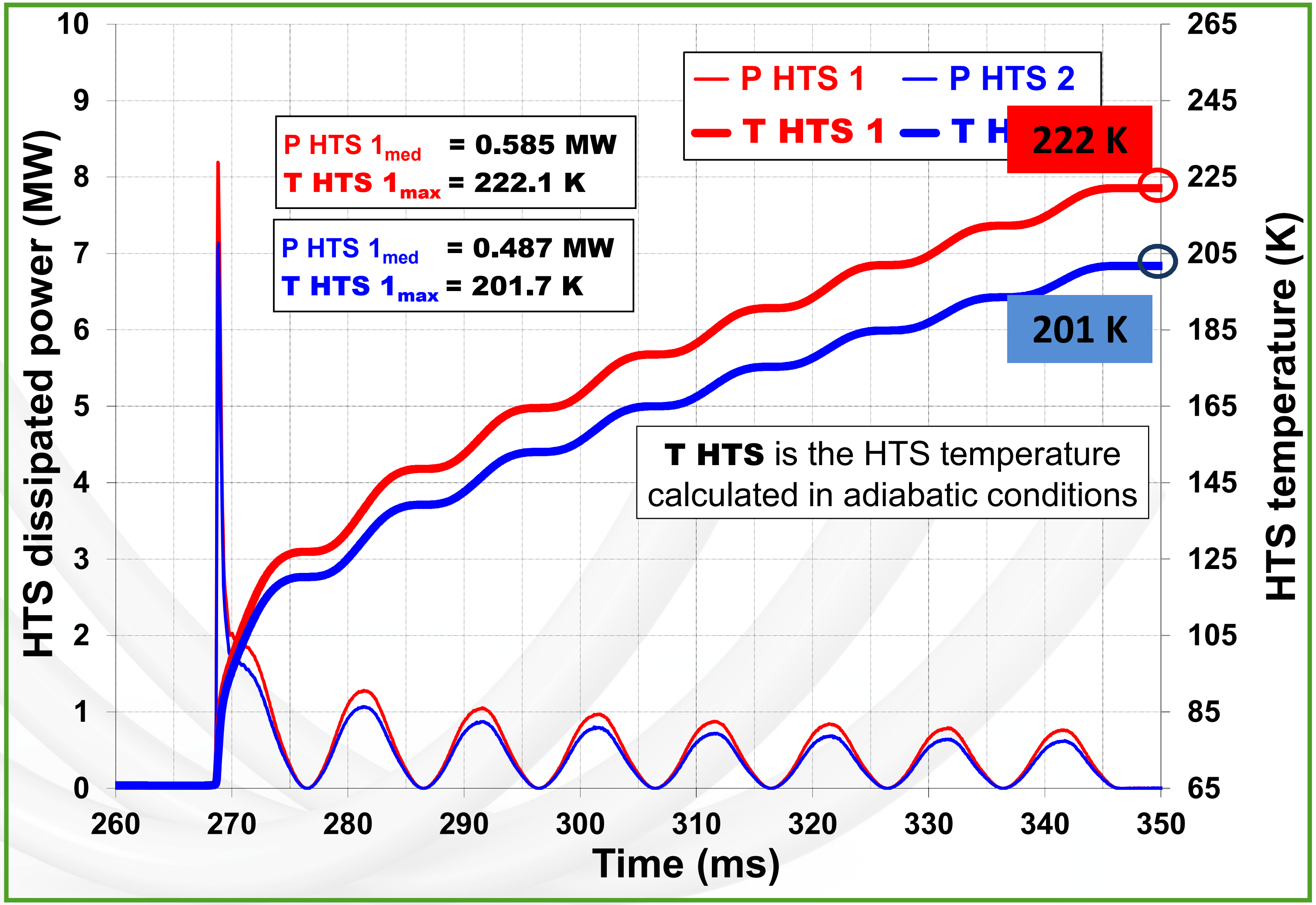


Italian SFCL Project (9 kV/15.6 MVA)
Full Short-circuit current tests



Peaks (kA)	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°
I_{HTS}	3.67	-0.77	0.64	-0.58	0.53	-0.50	0.47							
I_{PSC}	26.92	-6.27	22.16	-9.88	19.40	-11.99	17.72	-13.26	16.76	-13.99	16.18	-14.44	15.79	-14.71
I_{LIM}	15.16	-3.09	12.74	-4.96	11.19	-6.17	10.18	-7.03	9.57	-7.42	9.13	-7.77	8.89	-7.98
I_{PSC} / I_{LIM}	1.78	2.03	1.74	1.99	1.73	1.94	1.74	1.89	1.75	1.89	1.77	1.86	1.78	1.84

Italian SFCL Project (9 kV/15.6 MVA)
Full Short-circuit current tests



Cost effective FCL using advanced superconducting tapes for future HVDC grids

FastGrid

Superconducting Fault Current Limiter (SFCL):

- **First commercialization in medium voltage**
- **Strong interest in High Voltages (HV), especially in meshed HVDC grids (Supergrids)**

Supergrids:

A solution for the future to transmit very large renewable energies over long distances, smoothing generation & consumption variations.

Fault current management remains an hurdle.

Statement: *present HTS tapes are not suitable for HV FCL applications and enhancement of the operation security under HV is required.*

FastGrid ***Significant advances of the attractiveness of SFCLs by improving REBCO tapes, especially in their current limitation mode.***

Cost effective FCL using advanced superconducting tapes for future HVDC grids

In summary FASTGRID project aims at improving significantly existing REBCO conductor architecture to make SFCLs economically attractive for HVDC Supergrids. However, availability of such an advanced conductor will have an impact on virtually all other applications of HTS tapes.

FastGrid partners:

FastGrid details:

- H2020-NMNP-18 project (ID 721019)
- 42 months starting from January 2017
- Coordinator: CNRS (FR)
- Total budget: 9 M€ (EU cont. 7.25 M€)

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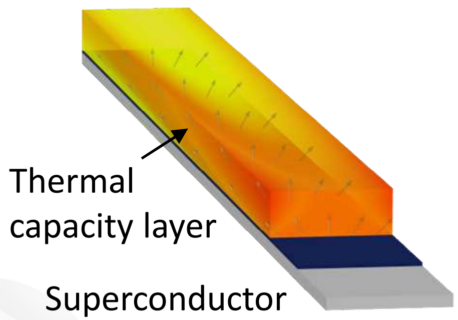
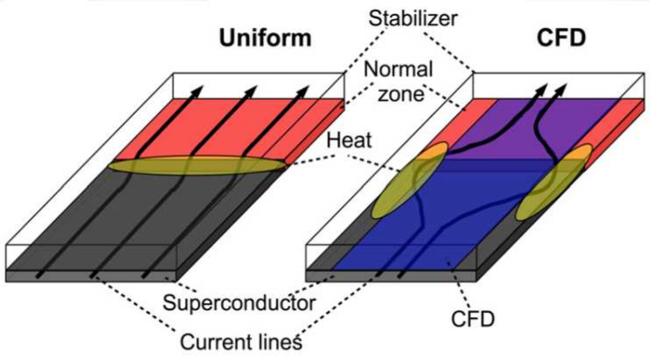
Cost effective FCL using advanced superconducting tapes for future HVDC grids

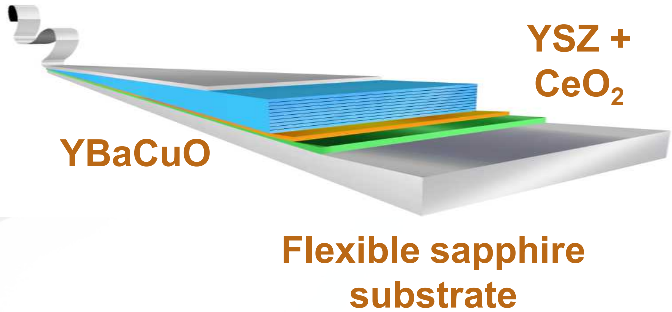
FastGrid

FastGrid main deliverables:

- **Advanced REBCO tape**
  - ➢ Low standard deviation in term of critical current over the tape length
  - ➢ Electric field higher than 100 V/m (50 ms)
  - ➢ Critical current higher than 1,000 A/cm-w at 65 K (self-field)
- **Emerging REBCO tape**
  - ➢ Tape with enhanced propagation velocity (CFD concept)
  - ➢ Sapphire substrate REBCO tape with ultra-high electric fields
- **Smart module of a HVDC apparatus**
  - ➢ Current and voltage in the range of 0.5/1 kA and 30/50 kV
  - ➢ New functionality such as quench detection through optical fibers
  - ➢ Extensive testing of the module in relevant operating conditions







SMES Applications

DRYSMES4GRID:
The Italian project for the design of a cryogen-free SMES

Starting Date: June 2017

Duration: 36 months

Technical Coordinator: Columbus

Total Budget: 2.7 M€

Contribution from MiSE*: 1.4 M€

SMES Prototype: 200 kW / 500 kJ

Conductor: MgB_2

***MiSE is the Italian Ministry for Economic Development**

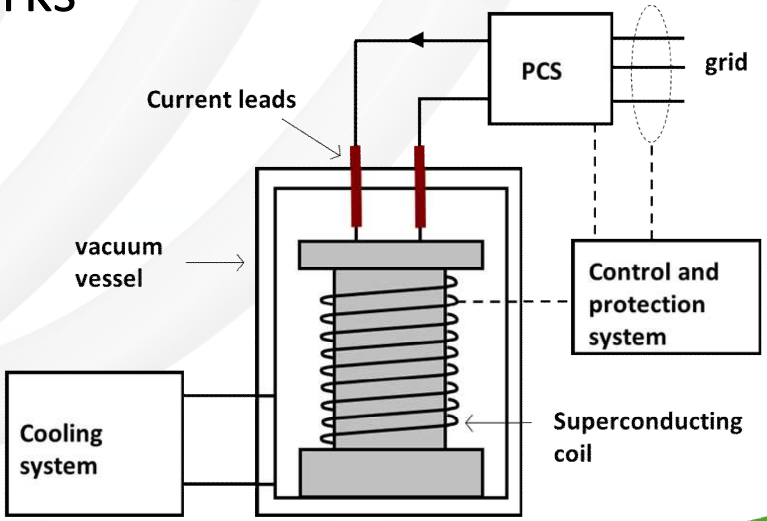
In-field testing of the SMES prototype will be performed at the RSE premises

DRYSMES4GRID

Aim of the project is to demonstrate the feasibility of a SMES (Superconducting Magnetic Energy Storage)

- Superconducting wire based on MgB_2 technology
- Cooling without using cryogenic liquid

Goal: technical and economical assessment of the benefit that a SMES can bring to real world networks



CSEA CASSA PER I SERVIZI ENERGETICI E AMBIENTALI

Ministero dello Sviluppo Economico

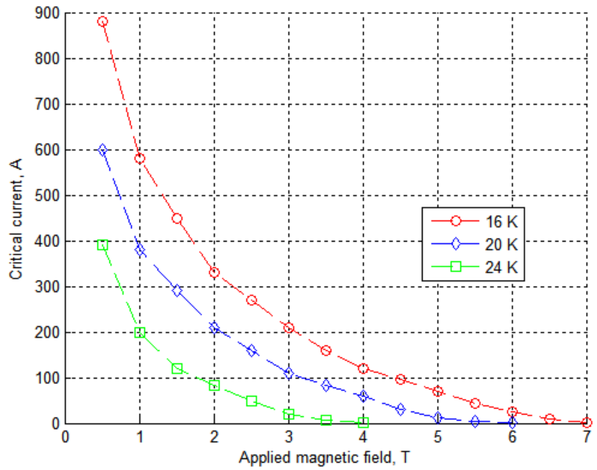
Ricerca sul Sistema Energetico - RSE S.p.A.

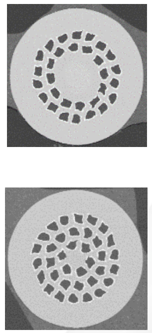
Main technical issues

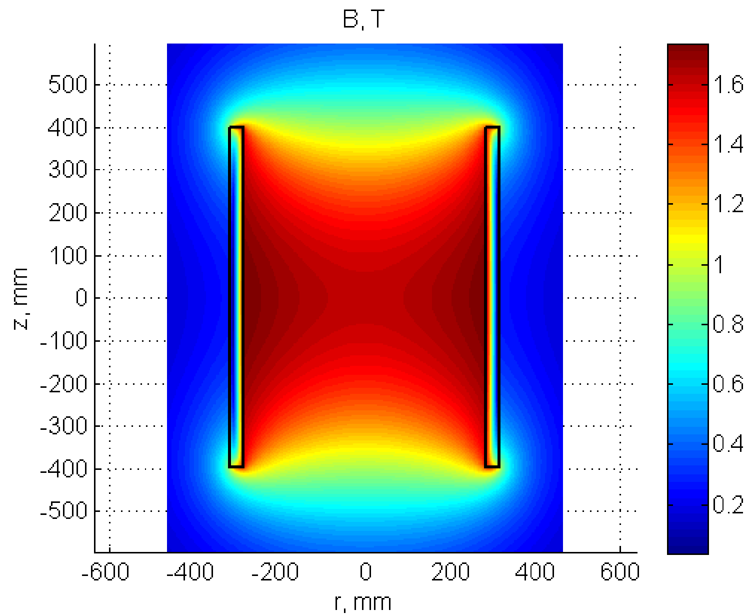
- Manufacturing of the SC wire, SC cable and winding
- Stabiliy of the winding during the fast charge and discharge
- Temperature uniformity
- Electrical insulation
- Cooling losses - Converter losses
- Realization of the power and control electronics for operation in the power network

Manufactruring and testing of a demostrator with 500KJ/200KW

Inner radius	**0.3 m**
Height	**0.8 m**
Cable type	**6 wire strands**







Main characteristics of a typical MgB_2 Conductor	
Nominal radius	1.13 mm
Number of filaments	36
Filling factor	0.14
Matrix	Ni 70%, Copper 20 %
Critical tensile strength	300 MPa
Critical current, 22 K, self field	550 A

CONCLUSIONS

- **A general outlook of the role that HTS applications actually play and will address in future power systems has been provided**
- **The role of International Energy Agency has been highlighted and especially the "*HTS Roadmap for the Electric Power Sector 2015-2030*" and the ongoing activities developed by the IEA HTS Technical Collaboration Programme**
- **Some key projects in Europe focusing on applied superconductivity in the power sector have been presented and their main features and challenges summarized**

Thank you
for your attention

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Superconducting Magnetic Energy Storage (SMES) Benefits

Power quality requirements of industry and digital economy
- Rapid response for either charge or discharge

Grid stability challenges posed by renewable energy sources
- Power is available when needed, not only when generated

High round trip efficiency vs. other storage technologies
- Minimal resistive energy losses in the s/c coil and solid state power conditioning

The time is right with recent improvements in HTS
- Superior performance characteristics
  - Ability to go to high fields – allow high energy density
  - High hoop strength of 2G HTS
- Continued performance/price ratio improvements

Clean and Green
- Safe - no chemical reactions, no toxins produced