4LP3-07

13th European Conference on Applied Superconductivity — EUCAS 2017, Geneva 17th - 21st September 2017

Conduction Cooled HTS Dipolar Magnet, Realization and Experimental Results

I. Dobrin[1], A. M. Morega[2], D. Enache[1], A. Dobrin[1], M. Morega[2], I. Popovici[1], A. Dobre[2]

[1]National Institute for Research and Development in Electrical Engineering, Romania,

[2]University POLITEHNICA of Bucharest, Faculty of Electrical Engineering, Bucharest, Romania

Abstract

The paper reports the realization of a dipolar superconducting magnet for high uniformity magnetic field generation [1], and the experimental results obtained. The magnet is aimed for various applications including particle accelerators. The adopted solution for winding distribution is of cosine type. The HTS coils are executed from YBCO tape, 6 mm wide [2,3]. The magnetic field, as the main purpose of the HTS magnet is designed to provide for a highly uniform (10^{-3}), high flux density magnetic field (~2.5T) in a warm bore, accessible from outside. The thermal regime for the HTS coils of the magnet is provided by a Gifford-McMahon cryocooler [4,5]. The coils performances and the tests results of the magnet are presented, compared with the design parameters.

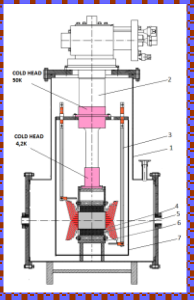
Acknowledgements

The project funded by National Authority for Scientific Research UEFISCDI, through PN II Program, trough the Contract no. 55/2014 is acknowledged.

MAGNET SYSTEM DESIGN

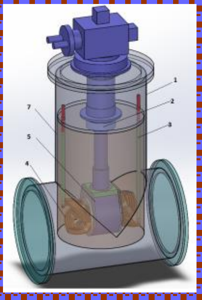
The main components of the dipole magnet system (DMS) are: the cryostat, HTS coils, the cryocooler. The cryostat has a specific design and an axial bore passing through the magnet in order to allow the charged particles acces to the magnet field zone.

Two Gifford-McMahon closed cycle cryocoolers are used as heat removal pump [2].



Schematic view of the DMS

1. Cryostat
2. Cryocooler
3. HTS Current leads
4. HTS coils
5. Iron shield
6. Mechanical Support
7. Thermal shield



CAD views of the DMS

The assembled HTS magnet – general view

SYSTEM CHARACTERISTICS

The main magnet system performances are summarized below:

- Magnetic flux density: 0-3T
- Magnetic field density uniformity (GFZ): 0,1%
- Volume of the GHZ: 2,35 cm^3
- Operating current:0 - 180A
- GFZ length: 100 mm
- Central channel D=60 mm

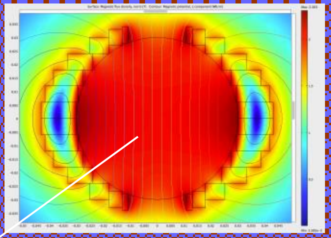
NUMERICAL SIMULATIONS

In superconducting state the Joule effect is null, therefore the magnetic field and heat transfer problems are uncoupled, and they may be solved separately.

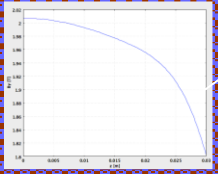
$$\nabla \times \left(\mu_0^{-1} \mu_r^{-1} \nabla \times \mathbf{A} \right) = \mathbf{J}^e$$

Steady state magnetic field, vector potential formulation.

A[T/m] is the magnetic vector potential, J^e [A/m²] is the external current density.



Dipole magnetic field generated by the winding cosine distribution



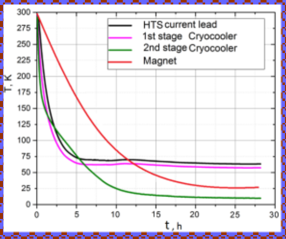
Magnetic field B variation (vertical)

Assembled HTS coils and their support

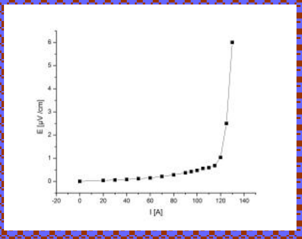
The HTS coils main characteristics

Coil Number	Number of turns	Resistance [Ω]	Inductance [H]
1	56	3.095	$1.15*10^{-3}$
2	56	3.017	$1.1*10^{-3}$
3	73	3.94	$1.8*10^{-3}$
4	68	3.41	$1.36*10^{-3}$
5	68	3.715	$1.59*10^{-3}$
6	73	4.43	$2.28*10^{-3}$
7	38	0.9123	$0.207*10^{-3}$
8	38	0.94125	$0.22*10^{-3}$

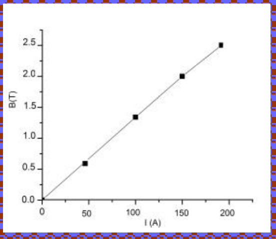
EXPERIMENTAL RESULTS



Cooling process of the magnet



Critical current for the 6 mm HTS tape



Load curve of the magnet

CONCLUSIONS

A design for a dipolar high temperature superconducting magnet, destinated to be used for particle accelerator is proposed, aimed for Extreme Light Infrastructure (ELI) project, Bucharest.
The magnetic field generated by the HTS magnet was numerical evaluated using COMSOL Multiphysics.
The electrodynamic forces inside the windings were also evaluated, using numerical simulation with COMSOL Multiphysics.
A special shape design for the cryostat was also realized, to allow cryocooler positioning and acces for the charged particles.
The HTS coils are executed with 6 mm wide YBCO tape from SuperPower [3].
Preliminary experimental results of the DMS are presented(cooling of the magnet, critical current of the HTS tape and the load curve of the magnet).
The magnet was finally cooled to 25 K and a magnetic flux density of 2.5 T was measured in the center of the magnet.

REFERENCES

[1]. A.M. Morega, I. Dobrin, M. Morega, A. Nedelcu, V. Stoica , (2015) "Design and Numerical Simulations of a Superconducting Dipolar Electromagnet Cooled by Conduction", Proc. of the 9th Intl. Symposium of Advanced Topics in Electrical Engineering ATEE 2015, Bucharest, Romania, May 2015, ISBN: 9781-4799-7514-3/2015 IEEE Xplore

[2] D. Enache, A.Morega, I. Dobrin, A. Dobrin, M. Morega, "Experiments on YBCO tape type high temperature superconductor junctions", ICATE, 2016 International Conference on Applied and Theoretical Electricity, October 6-8, Craiova, Romania, IEEE Xplore, 978-1-4673-8562-6/16

[3] Superpower, http://www.superpower-inc.com/

[4] A. Bejan, Heat Transfer, J. Wiley, New York, 1989

[5] SHI, http://www.shicryogenics.com/