HTS Dipole Magnet Model for the Persistent Current Operation

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***Abstract*—Recent advances in the fabrication of high-temperature superconducting (HTS) coils allow the design of superconducting accelerator magnets that work in a persistent current mode. Many various, rather low-field magnets in particle accelerators operate in the DC current mode. Fermilab designed, fabricated, and tested an HTS dipole magnet model that has 20-mm air gap and a magnetic field up to 0.5 T. The magnet has a primary copper coil that for a short period pumps the energy in the short-circuited secondary HTS coil. The current paper presents the design, fabrication, and testing of this magnet at liquid-nitrogen temperature.**

***Index Terms*—High temperature superconducting, persistent current, accelerator magnet, magnet test.**

I. Introduction

HIGH temperature superconducting (HTS) magnets are of great interest in the future applications. This paper describes activity conducted at Fermilab for the development of an HTS accelerator dipole magnet that works in a persistent current mode. Previously, quadrupole magnets with circular HTS coils were used as a test bench for novel HTS coil configurations [1]–[6]. The stable current induced in HTS short-circuited loops generate a highly stable magnetic field in the quadrupole aperture [7]–[9]. These successful tests made visible the design, fabrication, and testing of HTS dipole magnets.

II. Short-Circuited HTS Coils

Most high temperature superconductors are manufactured in the form of a thin tape. For HTS coils, several issues have been found difficult to resolve:

- It is difficult to fabricate superconducting splices between HTS conductors.
- The quench propagation velocity in the multi-turn HTS coils is very slow, which could easily overheat and damage the superconductor. Additionally, the quench detection and HTS coil protection systems are complicated.
- The HTS multi-turn coil performance is limited by the lowest superconductor property along the superconductor tape length. Even small defects or errors while winding this brittle conductor could completely damage the coil.

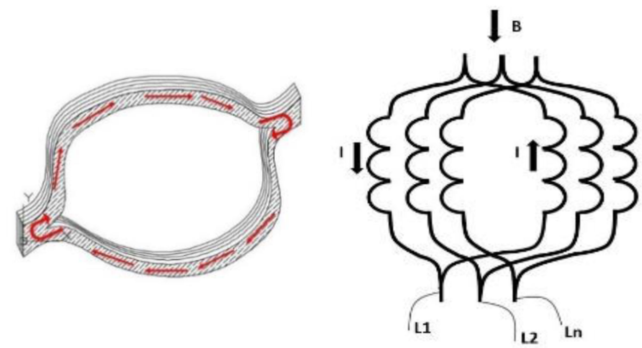

Fig. 1. HTS coil assembled from parallel loops. Arrows show the circulating current ***I*** directions. ***L1 – Ln*** conductor loops, ***B*** – flux density.

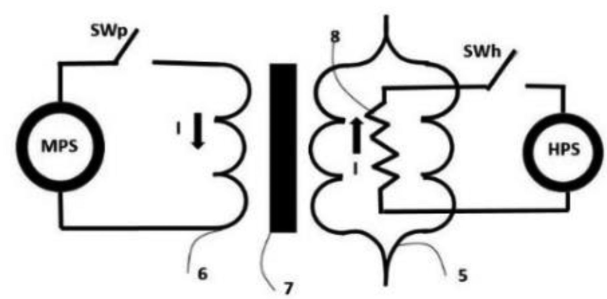

Fig. 2. Magnet system schematic. MPS and HPS – main and heater power supplies, 6 – primary winding, 5 – secondary HTS coil, 7 – magnet core, 8 – heater, SW – switches.

The main idea of the proposed HTS coil is to use a stack of HTS tapes and cut them in a longitudinal direction without cutting at the ends. Coil ends should have enough length to transport the circulation in the loop current. After cutting, the stack of loops is formed in a round configuration as shown in Fig. 1.

Several HTS coils were successfully tested in various magnet configurations [9]. Inducing a continuously circulating current in the HTS coil involved using the current transformer schematic shown in Fig. 2. The primary and secondary coils need to be strongly inductively coupled. Initially, the main power supply (MPS) ramps up to the maximum current, inducing the opposite current (Lentz's law) in the HTS secondary. If both coils are 100% coupled, then the current induced in HTS is equal to the total primary winding ampere-turns. In the next step of the

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