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Applied superconductivity for the electric grid

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Objective – This paper discusses the application of high temperature superconducting (HTS) devices in the electric grid. It first introduces the commercial HTS materials commonly used for grid applications. Then, three superconducting devices are discussed: the HTS cable to transmit high power at low voltage, the superconducting fault current limiter (SFCL) used in AC and DC power systems to limit fault currents, and the superconducting magnetic energy storage (SMES) to store energy. Some current projects, particularly in France, are presented.

Keywords – High temperature superconductor, electric grid, HTS cable, Superconducting fault current limiter, Superconducting magnetic energy storage.

1. Introduction

In this short paper, the two main types of HTS materials used for power system applications are introduced. Then, three HTS devices for the electric grid that are at the early stage of commercialization are presented: the HTS power cable, the Superconducting Fault Current Limiter (SFCL) and the Superconducting Magnetic Energy Storage (SMES).

2. HTS materials for the electric grid

There are two main types of HTS materials used for power system applications: BSCCO and REBCO [1]. They come either in bulk or in tape form. In this article, we focus only on HTS tapes because they form the basis of coils and cables. BSCCO and REBCO HTS tapes have different architectures: BSCCO tapes consist of BiSrCaCuO filaments embedded in a silver matrix, while REBCO tapes consist of different layers including a micrometer thick REBaCuO layer (RE for Rare earth). They can both be used at 77 K, the temperature of liquid nitrogen (LN₂), which has the particularity of being an electrical insulator.

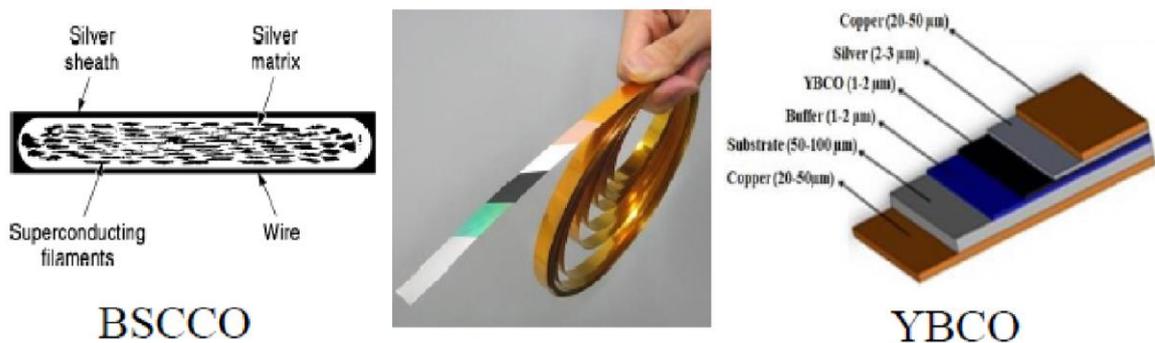


Figure 1 - Left: BSCCO tapes from Sumitomo, Japan. Middle: REBCO tape from Fujikura, Japan. Right: REBCO tapes from SuperOx, Russia.

3. HTS devices for the electric grid

The HTS power cable is a popular application of HTS materials for power systems. This is illustrated by various projects around the world [2,3]: LIPA, Ampacity, COMED, Superlink, etc. A French project named SuperRail between

SNCF Réseau, Nexans, Absolut System, GREEN and GeePs is ongoing. The goal of this project is to install a DC HTS cable system to feed the Montparnasse railway station in Paris. The structure of the HTS cable is illustrated in figure 2. It will be made with commercial REBCO tapes.



Figure 2 - View of the SuperRail DC HTS power cable (3500 A, 1500 V) [11].

The resistive Superconducting Fault Current Limiter (r-SFCL) has a strong industrial potential. It consists of a long length of HTS tapes wound as a non-inductive coil (Figure 3). The HTS changes from a superconducting state to a resistive state when the current passes a threshold, called critical current. Today, it is mainly used in AC grids [4-6]. A French project between GeePs, RTE and GREEN in collaboration with the Institute of Engineering of the UNAM, in Mexico, has been carried out to study the feasibility of using the SFCL as a Superconducting Power filter in DC grids [7-10].



Figure 3 - Left: non-inductive coil for SFCL ($\phi 690$ mm) [10]. Right: Inductive coil for SMES ($\phi 240$ mm) [12].

The Superconducting Magnetic Energy Storage (SMES) is one of the solutions to store electric energy in the electric grid. The idea is to inject a current into a large inductive superconducting coil (Figure 3) to store the energy as magnetic energy. By short-circuiting the coil by a superconducting switch, the current can flow without losses. The Institut Néel/G2Elab is working on the realization of REBCO magnets, within the framework of the BOSSE project, which aims at the realization of a REBCO magnet of 12 T / 1 MJ used as SMES [12].

4. Results and discussions

The current cost of HTS tapes remains an obstacle for industrial applications for power grids, but the prospects for reducing this cost in the medium term are very promising and the cost can be balanced by the technical aspects. Beyond that, the HTS device is sometimes the only technical solution for the application requirements.

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