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Research paper

Study of the electromagnetic characteristics of multiple HTSPPT modules based on the configuration of toroidal structure for inductive pulsed power supply

Cunshan Zhang, Xinxin Zheng, Haitao Li*, Zhenmei Li, Tao Zhang, Can Jiao

School of Electrical and Electronic Engineering, Shandong University of Technology, 255000 Zibo, China

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A B S T R A C T

High temperature superconducting pulsed power transformer (HTSPPT) is an important device for pulsed power supplies. It consists of a superconducting primary and a normal conducting secondary, which is used for energy storage and current amplification. The critical current density, the energy storage, and the coupling coefficient are three main performance indexes. They are affected by the geometry parameters of HTSPPT modules, such as the height and the width of the superconducting coils. In addition, the hoop stress of the HTSPPT coils is limited by the maximum tensile strength of high temperature superconducting (HTS) tapes. In this paper, Bi-2223/Ag HTS tapes are selected as the wire of primary inductor and the toroidal structure model is selected for multiple HTSPPT modules. The relationships between the geometry parameters of HTSPPT modules and the electrical performance are studied.

1. Introduction

With the advantages of high temperature superconductors, the high temperature superconducting (HTS) coils for different purposes have been developed. One of the most promising applications is magnetic energy storage (SMES) [1–3]. Combining SMES with pulsed power supplies reduces the volume of an electromagnetic launch systems [4,5].

High energy density, low electrical loss, and high current pulse are required for pulsed power supplies driving an electromagnetic launcher. HTSPPT is an important device for superconducting inductive pulsed power supplies [6]. It consists of a HTS primary winding and a resistive secondary winding. The HTS primary winding is usually used for energy storage and the secondary winding is usually used for generating large current pulses. Although HTSPPT integrates energy storage and pulse compression together, the modular design of HTSPPT is needed to reach tens or hundreds of kA current. In the previous studies, the circuit topology with multiple HTSPPT modules was designed for a superconducting inductive pulsed power supply [6–8]. As the coil geometric parameters of HTSPPT modules and the arrangement method significantly affect the electrical performance of the system, the relationships between the geometry parameters of HTSPPT modules and the electrical performance are studied by finite element (FE) simulations in this paper.

2. Design of structure model

The toroidal structure is selected as the arrangement mode of multiple HTSPPT modules, as shown in Fig. 1. To minimize the volume, a compact arrangement is used for the multiple HTSPPT modules. In each module, the primary winding consists of two HTS coils connected in series, and the secondary winding consists of three copper coils connected in series, as shown in Fig. 2.

As the performance of Bi-2223/Ag HTS tapes has been obviously improved, the production costs have been greatly reduced in recent years. Bi-2223/Ag tapes are chosen as the HTS wire of the HTSPPT primary windings. The specifications of the Bi-2223/Ag tapes provided by the Innova Superconductor Technology (InnoST) company are shown in Table 1. [9].

To minimize the volume of whole system, a compact arrangement method is used for the configuration structure of the multiple HTSPPT modules, as shown in Fig. 3. The space between two adjacent modules is 10 mm, which filled with insulation materials and support structure for the HTSPPT modules.

Fig. 4 shows the parameters selected for the cross section for each single HTSPPT module. The symbols h and d represent the width and the thickness of the HTS coils, respectively. R_{av} is the average radius of the toroidal structure and r_{av} is the average radius of the single HTSPTT module. The height of the copper coil is 5 mm and the space between

* Corresponding author.
E-mail address: lihaitao840812@163.com (H. Li).

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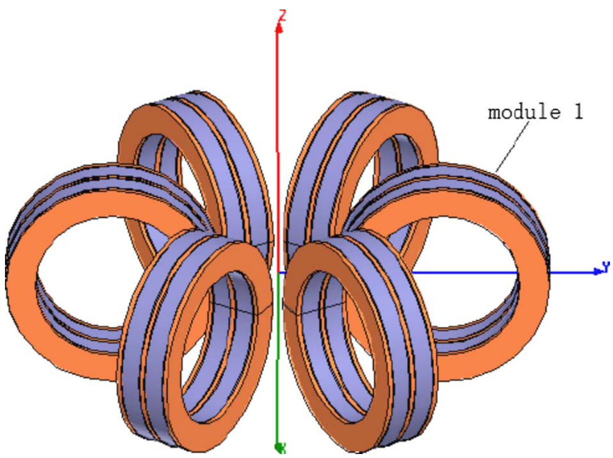

Fig. 1. The configuration of toroidal structure with six HTSPPT modules.

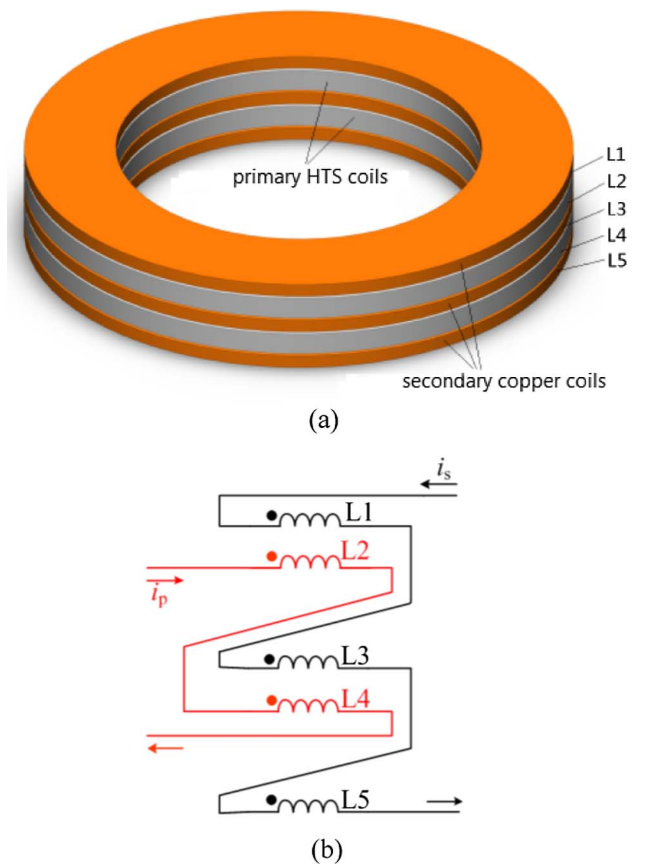

Fig. 2. The configuration of single HTSPPT module: (a) structural model, (b) connecting scheme.

Table 1
Specifications of Bi-2223/Ag tapes.

Bi/2223/Ag	Standard wire
Critical current density	12,000 A/cm^2 (77 K, 0 T)
Width of tape	4.2 ± 0.2 mm
Thickness of tape	0.23 ± 0.2 mm
Max. tensile strength	100 MPa (77 K, at 95% I_c retention)
Critical bending radius	30 mm (77 K, at 95% I_c retention)

coils is 1 mm. If r_{av} (95 mm) and the cross section area ($h \times d = 600\ \text{mm}^2$) of primary HTS coil are kept, the amount of HTS tapes in each HTSPPT module is constant. In order to study the

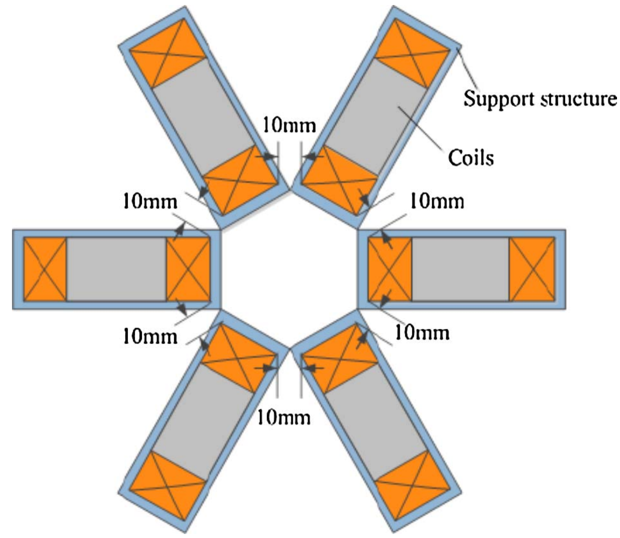

Fig. 3. Overall layout with six HTSPPT modules.

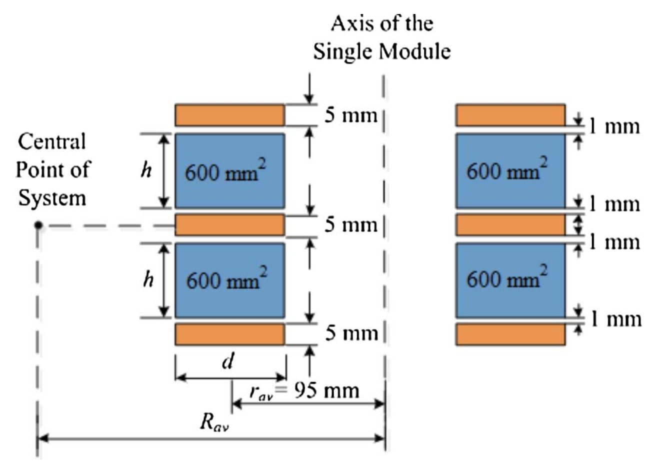

Fig. 4. Parameters selection of the cross section for each HTSPPT module.

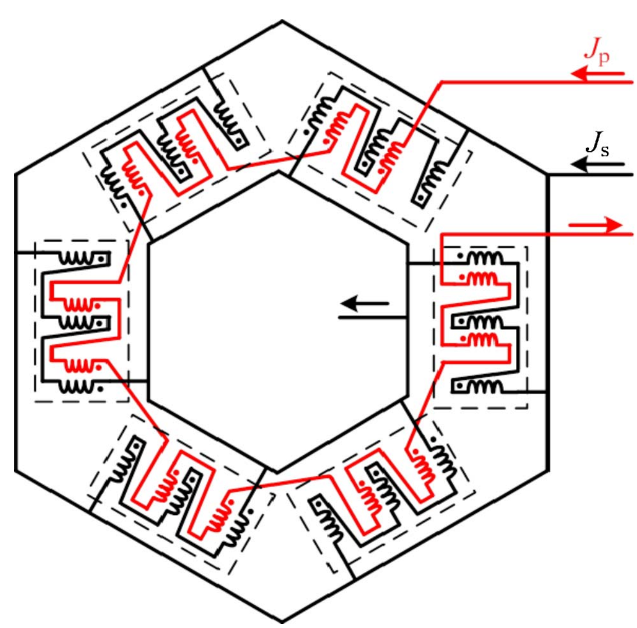

Fig. 5. The connecting scheme of the HTSPPT modules in the charging phase.