Seminar

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Institute for Plasma Research

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Title: Study of MgB_2 based Superconducting Current Feeders System for Fusion Devices

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Date: 25th October 2023 (Wednesday)

Time: 03.00 PM

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Abstract:

Current feeders system (CFS) is one of the most critical part of a large-scale superconducting (SC) magnets based fusion devices. One end of SC feeder is linked to the magnet, while the other end is connected to the power supply through optimized current leads (CL) to facilitate the magnet's energization. Since large-scale SC magnets contain huge stored magnetic energy in the range of MJ – GJ, the SC feeders are designed with considerations like, sufficient temperature margin for operation; better cryo-stability than that of main SC coils; capability to transfer stored magnets energy to safest way during quench and other abnormal events in SC magnets. So far, NbTi is a popular choice for SC feeders application. Ever since their advent, high temperature superconductors (HTS) are gaining wide attention for SC devices. Of late Magnesium diboride (MgB_2) that superconducts near 39 K [1], has emerged as the most versatile HTS wire solution for SC applications. It is a highly coveted HTS option owing to its cost-effectiveness in terms of raw materials availability, low specific weight, and reduced anisotropy compared to cuprate based HTS tapes. It presents a viable alternative for applications with moderate magnetic fields, such as MRI magnets and SC feeders for large magnets, as it offers a decent critical current density and lowers cryogenic operational costs. This opens up possibilities for its use in SC current feeders for fusion devices like Tokamaks and Stellartors, where it can enable efficient cooling within the temperature range of 10 K – 25 K even at reduced helium mass flow rates.

This thesis covers a systematic study involving physics design of 10 kA rated MgB_2 SC feeder for Steady State Superconducting Tokamak (SST-1) and proof of principle experiments for its current feeder system. Initially a comprehensive 1-D steady-state thermohydraulic analysis is conducted on MgB_2 feeders cooled by helium at 4.5 K, 4 bar (a) for toroidal field magnets of SST-1. Our findings indicate that the proposed feeders provide a substantial temperature margin exceeding 15 K, in contrast to existing NbTi based SC feeders having 1.5 K – 2 K margin. The results also reveal that such feeders offer much higher temperature margin at lower mass flow rates and reduced pressure drop, resulting in lower pumping power requirements for cold circulator and potential cryogenic plant capacity savings [2]. As an extension of this study, feasibility of MgB_2 feeders with 20 K helium gas cooling is studied to assess its suitability for safe operation. Analytical results suggest that even at 20 K, proposed feeders can provide improved stability and potentially save significant cryogenic capacity [3].

As a first step to prototype MgB_2 feeder, we used composite MgB_2 wires having Monel (Ni-Cu alloy) as an outer sheath. Monel has low wettability for solder materials which leads to difficulty in fabricating good quality of SC joints using conventional soldering methods. To address this issue, SC MgB_2 wires joints are prepared using copper electroplating technique for developing bottom joints of a 3.3 kA rated HTS CL [4]. The developed MgB_2 joints are cold tested as an intermediary SC-link between HTS CL and NbTi shunt [5]. Subsequently, a meter long 3.3 kA rated MgB_2 shunt is developed in-house and characterized in detail with HTS CL pair up to its full rated current with maximum current ramp rate of up to 300 A/s [6]. The present experiments demonstrate that prototype MgB_2 shunt exhibits much promising results with HTS CL as compared to NbTi. In this presentation, several of the reported results, experimental findings and potential future developments are discussed.

References:

[1] J. Nagamatsu, *et al.*, *Nature*, 410, pp. 63–64, (2001). https://doi.org/10.1038/35065039
[2] N. Bairagi and V. L. Tanna, *IEEE Trans. App. Supercond*, vol. 31, Issue 4, Art no. 4801905 (2021)
[3] N. Bairagi, V. L. Tanna, and D. Raju, *IEEE Trans. App. Supercond*, vol. 32, no. 6, Art no. 4802305 (2022)
[4] N. Bairagi, V. L. Tanna *et al.*, *Physica C: Applied Superconductivity and its Applications*, vol. 601, 1354108, (2022)
[5] N. Bairagi, V. L. Tanna, *et al.*, *IEEE Trans. App. Supercond*, vol. 33, no. 4, pp. 1-5, Art no. 4801408 (2023)
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