State of the art and perspectives of LNCMI pulsed magnets at neutron sources

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Recently, several technological breakthroughs have confirmed the practical feasibility of superconducting solenoid magnets generating more than 30 T, based on a large traditional low-temperature superconducting (SBT) magnet, in which an insert based on high temperature superconductors (HTS) is introduced. In addition to a very significant reduction in electrical energy consumption, they also open up new experimental possibilities, such as experiments of very long duration or experiments that require very low levels of electrical and mechanical noise, impossible to achieve with resistive magnets.

To show the unprecedented capacity of HTS coated conductor to generate very high field at 4.2 K, we have developed a very compact HTS insert within a strong CNRS-LNCMI /CEA–DACM collaboration that could be tested in a 20 T 170 mm large bore resistive magnet available at LNCMI. As the HTS magnets must be effectively protected against transition to the normal state (quench), currently one of the major bottleneck in their use, this robust environment allows to focus on the operation and protection modes under high magnetic field of such an HTS insert.

We introduce the innovative "metal-as-insulation" (MI) winding technology to improve the quench protection. The co-winding of a superconductor with a metal ribbon, without isolation nor impregnation, allows the current to redistribute in the event of a local defect, conferring on the insert a self-protected character in case of quench. This self-protected character is shared with the non-insulated (NI) coil concept, but the additional turn-to-turn resistance brought by the metal co-wound ribbon reduces drastically the important time constant observed in NI coils. Moreover, in addition to thermal protection, the metal ribbon participates to the mechanical strength of the coil.

The HTS insert made of 9 double pancakes of a 6 mm wide HTS tape and with a 38 mm cold bore compatible with the concept of user magnet reached a world record central magnetic field of 32.5 T of which 14.5 T are produced by the HTS insert. This result also validated the "metal-as-insulation" concept for the first time under such high field. The use of MI coils that can surpass the current limit without damage is an inestimable way to test HTS windings close to their limits and to assess realistic safety margins.

As a follow-up, the European Infradev design project SuperEMFL was launched in January 2021 for designing a suite of beyond-state-of-the-art 30 to 40 T all-superconducting user magnets to be deployed at the EMFL facilities or at other research infrastructures, while the PIA3 FASUM project, officially kicked in December 2021, aims at the fabrication of such a 40 T class all-superconducting user magnet to be implemented at LNCMI Grenoble which will consist in the challenging combination of a LTS magnet and a high field HTS insert.

Expanding knowledge on stability, quench protection, structural integrity, and electromagnetic design will be extraordinarily useful for the design of other magnet systems such as high-field magnets suitable for different types of neutron beamlines at the ILL or ESS, or for X-Ray beamlines at ESRF.

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