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VIEWPOINT

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Viewpoint

Toward a new paradigm in quench detection for superconducting magnets? 'Quench detection for high temperature superconductor magnets: a novel technique based on Rayleigh-backscattering interrogated optical fibers (RIOF)'

Lucio Rossi
European Organization for Nuclear Research, CERN, CH-1211 Geneva 23, Geneva 1211, Switzerland

This is a viewpoint on the letter by F Scurti *et al* (2016 *Supercond. Sci. Technol.* **29** 03LT01).

Use of optical fibers for quench detection in HTS magnets may enable a breakthrough in magnet technology. HTS materials are on the verge of becoming a real asset for high field magnets. There is a demand of high field solenoids (>25) both for laboratory high field magnets [1] as well as for NMR system, where the new frontier is now fixed at 1.2 GHz [2]. Also fusion community is considering HTS 18 conductors for DEMO, on one side to open the possibility to operate at higher fields with respect to the ones of ITER, and to improve the temperature margin available for conductors. More recently, the particle accelerators community is also considering use of HTS based superconducting magnets for the next future colliders after LHC and its high luminosity upgrade, [3, 4]. The characteristics of accelerator magnets is that HTS are needed for field in excess of 15 T (dipole magnet coils generate half the field than of an equal coil thickness in solenoid configuration). A characteristics of accelerator application is that the operating temperature will probably remain at LHe, since the high overall current density at high field is the key properties for these type of magnets (rather than high temperature). Indeed for accelerator community HTS should be actually called *HFS*, high field superconductors.

While HTS properties are improving in an impressive way, the very slow quench propagation may turn out to be a real impediment to their use in real large —and expensive—systems, whose safety must be assured in any condition. Since the quench propagation velocity is typically hundreds time smaller than for LTS, use of classical voltage taps, the workhorse of any quench detection system, may not be efficient enough. The delay in detecting a quench, especially when magnet is operated far from the critical surface (which is the case in large systems), may be too long. Various experiments have shown how easy it is to damage and even to burn HTS coils, especially at low temperature, where the advantage of very large $J_{\mathrm{operating}}$ in combination with large field and stored energy as well as with small amount of stabilizer may turn into a danger.

The letter of Scurti, Ishmael, Flanagan and Schwartz is the most recent one published by the Schwartz group after many years of investigating innovative methods of magnet protection, more suitable to HTS magnets [5–7]. The group is pursuing a quench detection system based on temperature detection by means of optical fibers. The main idea is to detect directly the key parameters, the coil temperature, rather than relying on quench detection via voltage growth. Fiber-glass co-wound with the conductor offers the possibility to detect the quench at a very early stage and have been intensively in the last year by other groups. The letter of Scurti, Ishmael, Flanagan and Schwartz presents the first experimental evidence of the clear superiority of fiberglass in detecting a quench in superconducting windings over voltage taps, by using Rayleigh backscattering.

The authors claim superiority of this technique over the more classical FBR technique and Brouillon scattering detection [8, 9]. Rayleigh back-scattering interrogated optical fibers (RIOF) offer indeed a much greater spatial and time resolution, virtually limited only by data acquisition speed and real time data processing capability. One other great advantage of RIOF is the use of simple commercially available fibers, without the need of inscribing the UV grating.

The experiment is well described and, while it has been carried out at liquid nitrogen, the letter offers a convincing argument for its possible extension to the liquid helium temperature domain. The topology with fiberglass embedded in the turn-to-turn thin edge insulation seems more promising than the one in which the fiber is atop the tape (over the wide face), for use in large multi-layer coils.

Most of the technical and engineering problems, like positioning and engineering fiber-glass integration in a cryogenic and magnet environment are common between FBR and RIOF, which certainly helps the continuous development. While the letter signs a point in favor of the Rayleigh backscattering technique, we do not have a final answer, yet, on which will become the system of preference for fast temperature raise detection in a superconducting coil. However its main disadvantage, the huge data storage and fast on-line data processing, may be overcome in a smart way (as indicated in the letter), by suitable selection of the data sample. Certainly, continuous future improvements in data acquisition and processing systems will help, too.

The key points is that the need of HTS coils at high field and high current density is driving a revolution not only in coil technology but also in quench detection and protection. For a 4.2 K operating temperature, envisaged for very high field magnets, a smart use of fiber-glass in presence of the large difference between T_{op} and T_{cs}, may enable to design a quenchless magnet. Temperature raise can, indeed, be detected before it has time to drive the coil—or a portion of it—to normal state, allowing discharging the magnet before a quench is actually developed. This may be the new paradigm that this technology is perhaps promising: by early detection of temperature onset and fast discharge, eliminating quench and its consequences in superconducting magnets! As all we know, preventing is much better than repressing!

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