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Superconducting Magnet Energy Extraction with Varistors to Reduce Quench Voltages and Hot-Spots

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Superconducting magnet protection must address two main areas of the magnet and circuit performance, namely Conductor Hot-Spots and Circuit Voltages. Both hot spot and voltage operational maximums are during the superconductor's transition called a Quench. Historically high voltages have resulted in many damaged and destroyed magnet coils so reducing voltages is a preferred direction for designs. In an ideal design the Hot Spots should be limited to a level below the point where the thermal expansion starts to develop shear and direct stresses: this is at about 100 K for most materials. For magnets that use energy extraction to external loads, either fixed to the cold coil or at room temperature outside the cryostat, for a given magnet current the value of the maximum allowed voltage imposes the value of the energy extraction resistor. This determines, together with the magnet inductance, the time the energy is removed and thus the hot spot.

If we simply replace the resistor with a high-energy voltage-dependent resistor (varistor), we can extract more energy for the same maximum voltage because the self-adjusting resistance of the varistor reduces the extraction time.

This paper presents: the Varistor's warm and cold designs, the variety of possible protection circuits, and many test event data from several superconducting magnet cold tests.

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