环形正负电子对撞机
Circular Electron Positron Collider

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Quench Protection Design and Simulation of a 13-T Superconducting Dipole Magnet

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Abstract--On the basis of the design and test of a high field dipole magnet named LPF1, which reached a peak field of 12.47 T in 2021, the new model LPF3 made up of 6 Nb_3Sn coils has been designed at IHEP. In this magnet, the Nb_3Sn coils will provide a 13-T field at the operating current of 7580 A. Finally a design of using varistor and quench heater for protection has been adopted.

Table 1 The main parameters of the magnet LPF3

Parameters	Unit	Value
Number of apertures		2
Aperture diameter	mm	50
Operating current	A	7580
Designed main field	T	13.01
Operating temperature	K	4.2
Inductance of magnet	mH	74

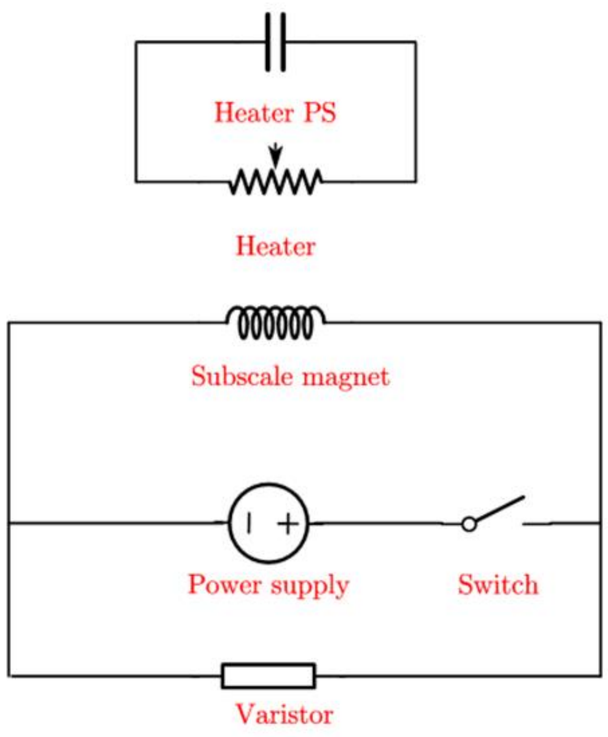

Figure 1 The designed quench protection circuit

Figure 2 The design of the quench heater

Analysis--A 1-D adiabatic model was built in finite element software according to the following heat balance equation. In this model, the whole magnet is spread as a long cable. Only the thermal propagation along the cable will be taken into consideration.

$$A_i\rho_i Cp_i\frac{\partial T_i}{\partial t}-\frac{\partial}{\partial x}\left(A_i k_i\frac{\partial T_i}{\partial x}\right)+\sum_{j=1}^{N}\frac{(T_i-T_j)}{H_{ij}}=\dot{q}_{ext}+\dot{q}_{Joule}$$

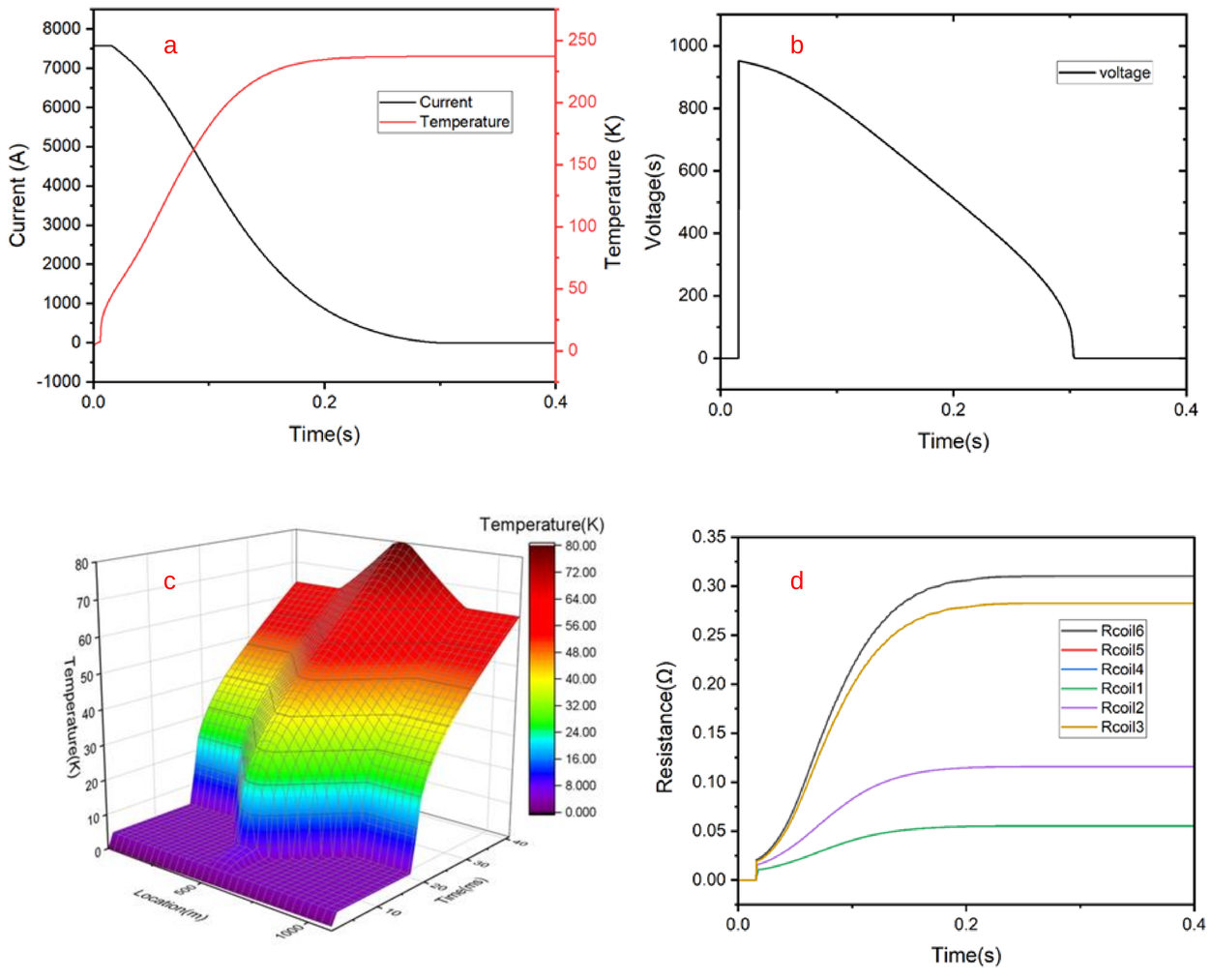

Figure 3 Simulation results

Results--Figure 3 show the simulation results with varistor and quench heater when the voltage threshold and the validation time are set as 100 mV and 10 ms, including the current decay, hotspot temperature, the terminal voltage during the quench process and the temperature near the hotspot. Figure 4 also indicates the hotspot temperature with different protection parameters. The method has been verified to be feasible as the hotspot temperature can be kept under 280 K with a terminal voltage lower than 1000 V.

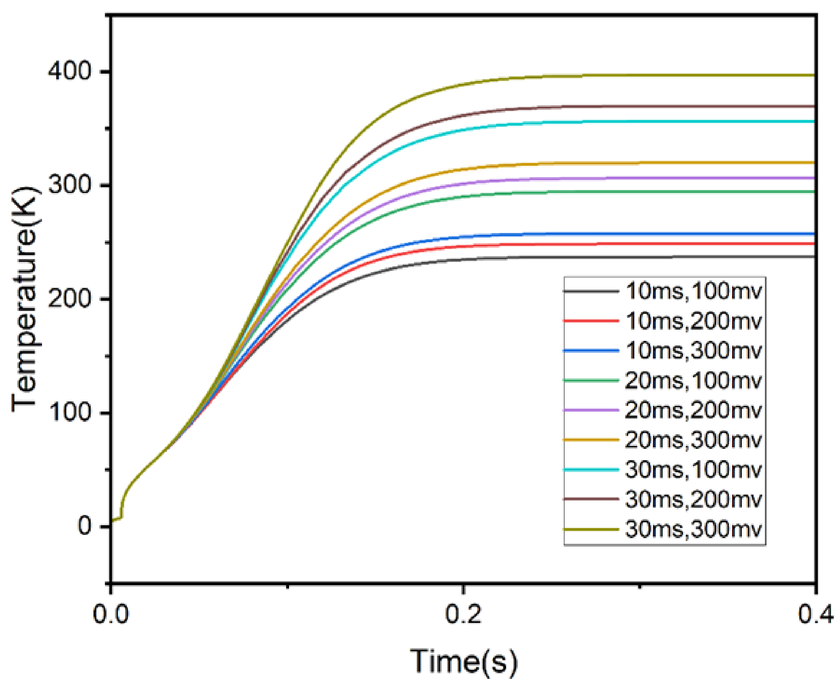

Figure 4 The hotspot temperature with different protection parameters