Refinement and application of a generic CFD toolkit covering the heat flows in combined solid-liquid systems to investigate thermal quench limits of superconducting magnets

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LHC Main Dipole Magnet

Numerical Tool Development

$$\rho C_p \frac{\partial T}{\partial t} = \text{\nabla \cdot } (k \text{\nabla} T) + q_v$$

$$\rho \frac{\partial \lambda}{\partial t} = \rho \lambda = \frac{T - T_{\text{Cur}}}{T_{\text{Cur}}}$$

Liquid Helium penetrates the cables through porous insulations

The LHC Quench Test Experiment

Pre-Processed Input Data

Determining The He Volume Fraction

Application To The MB(A) LHC Dipole

The temperature margin in the squared region is $< 0$. A quench is expected in that scenario

Variation of LHe in Fishbones & Insulations

Conclusions

FLUKA shower simulations to evaluate the peak power density deposited in the magnet coils during the quench test.

ROXIE computes the temperature difference that the coils can undergo before transitioning to a resistive state (temperature margin).

The numerical model we developed provides a quantitative insight into which parameters, in the design of the magnet and the actual setting of the experiment, are significant in the cooling mechanism. Under the present assumption that $2\% \leq \varepsilon_{\text{Fishbones}} \leq 6\%$ (values deduced from the quench test), $0.03\% \leq \varepsilon_{\text{Insulations}} \leq 0.15\%$, and the observation that the variation in $T_{\text{Margin}}$ for each of them individually is comparable to $\pm 5\%$ in power deposition, we’d postulate with some reserve that the spread in MQE of the 1232 LHC main dipoles could be $10\%$: $11.7 \text{ mW/cm}^3 - 14.3 \text{ mW/cm}^3$.