

§3. Quench Analysis of the Helical Coils of LHD

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Composite-type superconductors with NbTi/Cu compacted strands and pure aluminum and copper stabilizers are used for the helical coils of the Large Helical Device (LHD) with the nominal current of 13.0/17.3 kA in the Phase I/II operation conditions, immersed in the liquid helium of 4.4/1.8 K. Since the helical coils will possess a large amount of magnetic stored energy (up to 1.6 GJ in the Phase II operation), it is very important to extract their energy quickly and safely in case of a quench. In this respect, we have carried out an analysis on the discharging process of the helical coils by taking into account the joule heating in the propagating normal zones as well as the AC losses during the field decay.

The discharging of the helical coils will be conducted using a specially developed circuit with fuses and dump resistors, which provides the time constants of $\tau_0 = 20$ s and/or 300 s for the exponential current decays. The 20-s discharge will be mainly used in case of a quench whereas the 300-s discharge will perform a fast ramp down during the power fault.

One of the characteristic features of the pool-cooled helical coil windings, being optimized for DC operations, is their fairly large AC losses during the field changes due to the strong inter-strand couplings in the superconducting cables. Since the evaluation of the precise AC loss power is rather difficult for the helical coils with their complicated structures, here we restrict ourselves to a simple calculation which deals only with the volume averaged power density within the whole conductors using the experimentally measured time constants for the coupling currents as well as the averaged values for the magnetic field.

Figure 1 shows the numerically calculated temporal evolution of a discharging process of the helical coil windings with $\tau_0 = 20$ s after a normal transition from the transport current of 13.0 kA. After a quench is detected, one second has to be waited in order to extinguish the high temperature plasma confined in the vacuum vessel. In the early stage of a discharge, the consumption of the liquid helium (~ 2.9 m³

before the discharge) is calculated for dissipating the heat generation in the windings. After the total liquid helium is lost from the helical coil cans, the released energy will be dissipated by raising the temperature of the coil windings as well as of the surrounding helium gas. The temperature rise of the windings is calculated by solving the time-dependent power balance equation in which the rate of the enthalpy increase of the conductor and the helium gas should be balanced with the power density of the released heat generation. After the coil temperature exceeds the sharing temperature for the transport current, the whole conductors are assumed to be normal, and the temperature rise becomes rapid due to the strong joule heating. The experimentally measured normal resistivity of the conductor is used to give the temperature-dependent joule heating power. In this process, the conductor temperature reaches up to ~ 30 K at the end of the discharge.

In case of the 300-s discharge, the AC loss generation becomes much lower and about 10 % of the total liquid helium is vaporized during the whole discharging process and the released helium gas can be recovered during the normal operation of the refrigeration system.

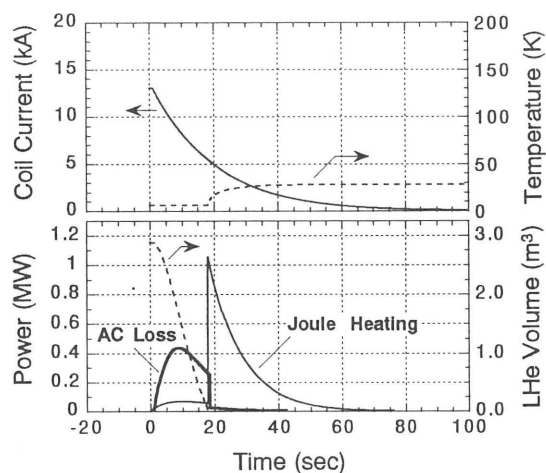


Fig. 2 Temporal evolution of the discharging process of the helical coil windings with $\tau_0 = 20$ s after a quench.

References

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- 2) Yanagi, N., Imagawa, S., Takács, S., et al., Proceedings for NIFS Symposium (1996)