§1. Observation of Coupling Currents with Very-Long Time Constants in LHD Poloidal Coils Using Hall Sensors

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Previous studies have reported evidence of magnetic field trapping/shielding with very-long time constants in large-scale superconducting coils which consist of cable-in-conduit conductors[1)]. The magnetic field trapping/shielding is probably caused by coupling current loops in the conductors. The coupling current will result in an increase in AC losses[1), 2)] and instability due to non-uniform current distribution. However, it is difficult to estimate the path and amount of the coupling current. In this study, Hall sensors were mounted in LHD poloidal coils and the coupling currents with long time constants have been examined.

Fig. 1 shows the locations of the Hall sensors. The sensors (model BHT921, Bell) are located 78 mm and 52 mm away from the inside surface of the Inner Shaping (IS) and the Outer Vertical (OV) coils, respectively. Two sensors were mounted for each IS coil (IS-U and IS-L) at toroidal angles of 23 and 203 degrees clockwise from the north. The vertical component of the field was then measured. The observations were carried out during the 7th and 8th plasma experimental campaigns. In the device engineering experiments, extended operations in which only IS and OV coils were energized were performed.

Fig. 2 shows the typical results observed in the device engineering experiments of the 8th campaign. The data indicate the residual field near the IS coil. The IS coils were energized up to 14 kA twice. On the day before this experiment, the IS coils were energized up to 14 kA with reversing the polarity. The observations showed the steady residual field of 0.5 mT. The polarity of the steady residual field changed with changing the polarity of the coil current. The steady residual field is probably caused by the magnetization of superconducting filaments. In addition, the changing residual filed of 0.2 ~ 0.4 mT was confirmed just after discharging the coils.

Fig. 3 shows the comparison between the residual fields just after the excitations. Although two excitations have the same maximum current, they have different hold times of a flat top. The first excitation has no flat top. The second has the hold time of 2 h. The decay of the residual fields was fitted approximately with an exponential function. The comparison between the residual fields indicates the difference not only in the amount of change but also in a decay time constant. The time constant is 600 s for no hold time and 1200 s for the hold time of 2 h. The steady residual field of 0.5 mT was not affected by the hold time. The change in the decay time constant can be explained by a circuit model for induced coupling currents if the coupling current has a broad distribution of time constants. The results then indicate the existence of the coupling currents with very-long time constants of more than 1000 s.

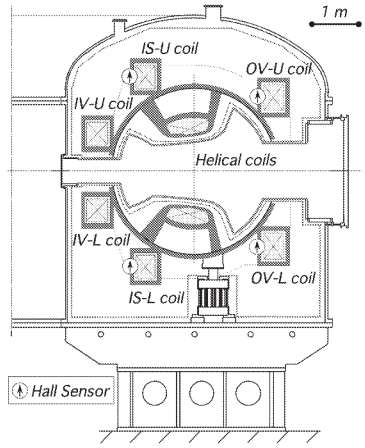

Fig. 1. Cross-sectional drawing of LHD and locations of Hall sensors.

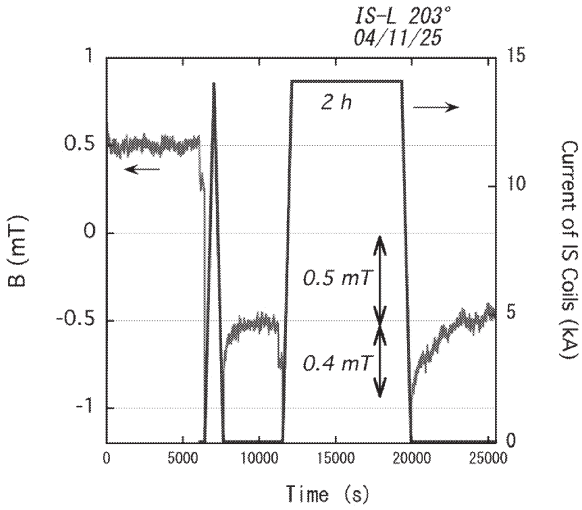

Fig. 2. Observed residual magnetic field after discharging the IS coils from 14 kA.

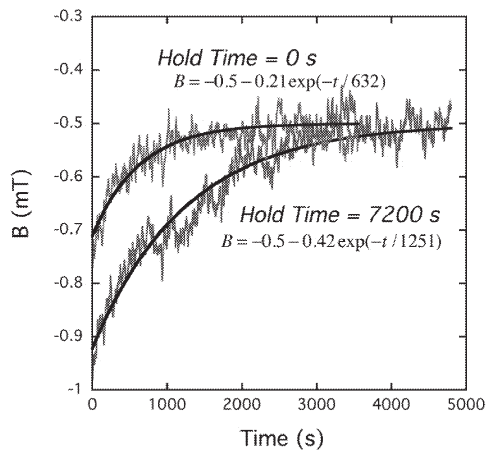

Fig. 3. Effect of the hold time of coil currents on the decay time constant of the residual field.

References
1) Hamajima, T., et al.: IEEE Trans. Appl. Supercond. 10 (2000) 812.
2) Takahata, K., et al.: Fusion Eng. Des. 65 (2003) 39.