§ 6. Current Control of Superconducting Coils for LHD Using H ∞ Scheme

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The coil system of LHD includes six sets of superconducting coils, and six dc power supplies are used to charge them. For these power supplies, the following conditions are required; the steady state control error is less than 0.01 % of the set value, the current settling time for 0.1 % of control error is less than 1 second and the control system must be robust against turbulence caused by the plasma experiments. To satisfy these requirements, two control systems using H∞ scheme were studied, designed and tested.

In usual operations, P controller based on the state vector is used but the control gains are limited by the stability requirement, which means the response time constant cannot make so small. The $H\infty$ design scheme is one of the solutions to satisfy both the robustness and fast response. We designed two types of $H\infty$ controllers, which have different characteristics, for the LHD power system. One, named $H\infty(1)$, is designed to keep the coil currents constant even if the plasma current is excited. The other one, named $H\infty(2)$, is designed to keep magnetic flux constant while a plasma experiment. With the $H\infty(2)$ control, the coil currents may be changed when plasma current is excited but the terminal voltages will be kept at almost zero. Figure 1 shows a ramp response of the $H\infty(1)$ controller. For the $H\infty(2)$ controller, a similar response was observed. When this response is compared with the case of P controller, it is pointed out that the $H\infty$ control realizes the better response than P controller.

Figure 2 and 3 show the reaction caused by a plasma current (I_p) with the $H\infty(1)$ and $H\infty(2)$ controllers. Figure 2 shows that the coil currents were kept at constant while plasma current lamp up and it's reached to flattop. When the plasma broke, the dIp/dt signal became too large and it over the dynamic range of the power system, the coil currents show some transient waveforms but it did not cause any instability. In figure 3, the coil current was changed to keep the flux constant and terminal voltages were kept at almost zero. When this scheme was applied to the LHD, it is clear that the rebound of coil current when the plasma shut down is smaller than the case of figure 2 or P controller, and coil currents return to their references immediately.

In the next campaign, the effect of difference of current response to the plasma characteristics will be studied.

References

(1)T. Ise, D. Etou, H. Chikaraishi, S. Takami, and T. Inoue, " Current Control of Superconducting Coils for Fusion Experimental Facility", presented at 19th IAEA Fusion Energy Conference, FT/P2-08, October 14-19, 2002, Lyon, France.

(2)D.Etou, T.Ise, and H. Chikaraishi, "Current Control of the Measurement" 2003 National Convention Record I.E.E.Japan, Vol.5, pp.257-258, March 17, 2003 (in Japanese).

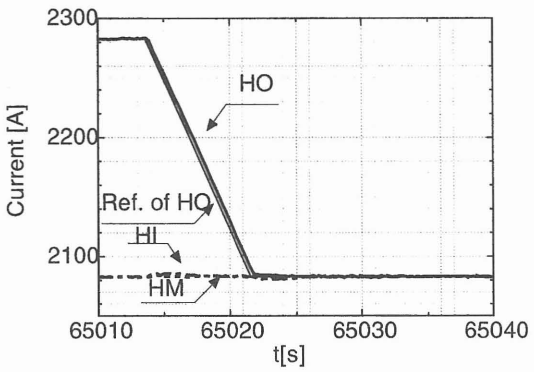

Figure 1: Ramp response of the power supply when $H\infty(1)$ control is applied.

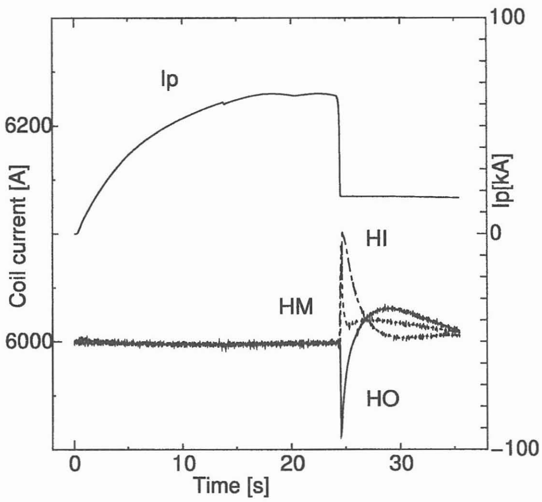

Figure 2: Reaction caused by a plasma current. $H\infty(1)$ control is applied.

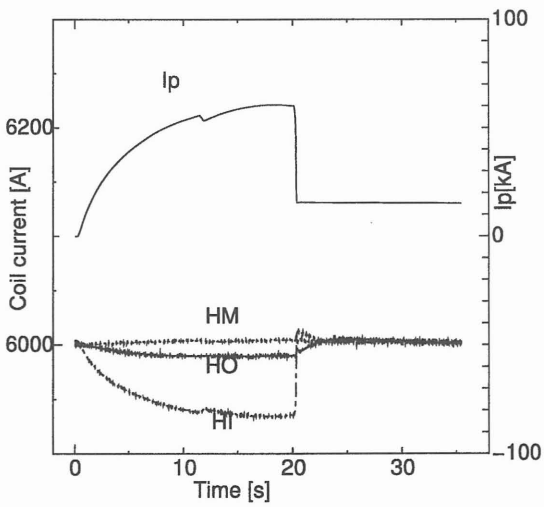

Figure 3: Reaction caused by a plasma current. $H\infty(2)$ control is applied.