§5. Study on Power Supply System for Superconducting Magnets Using Low Frequency Power Transmission

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Power supply systems for superconducting coils of magnetic confinement fusion devices are generally composed of ac/dc (alternating current / direct current) power converters, which rectify utility frequency ac to dc for exciting and de-exciting of coils, and some of them employ superconducting cables because the distance between power supplies and coils are relatively long. In this research, we propose the power supply system that employs low frequency power transmission for superconducting coils of fusion devices[1]. In the system, ac/ac power converters convert utility frequency ac to 1 ~ 10 Hz low frequency ac (LFAC) and LFAC power is delivered to ac/dc converters near superconducting coils with superconducting cables. Advantages of LFAC system over dc system are easy fault protection due to existence of current zero crossing point, easy conversion to large current by using transformers, and on the other hand, an advantage over utility frequency ac system is reduction of ac losses of superconducting cables.

An example of LFAC system for a fusion device is shown in Fig. 1. In this system, power system is connected to ac/ac converter through transformers and LFAC power is delivered to each components by using superconducting cables. We introduced a 12-phase double-star-connected thyristor rectifier for superconducting coil, as shown in Fig.2. This rectifier output low voltage and large current. A 12-phase configuration is applied to achieve reduction of the voltage ripple and short control cycle for high accurate current control. In addition, it adopts star connections due to reduction of the voltage drop and thyristors are employed as switching devices due to high reliability for the large current control. Fig.3 shows the block diagram of control scheme for the rectifier. It employs the proportional control scheme with gain K and a low pass filter (LPF) is applied to detected coil current. We conducted numerical simulation of charging and discharging the superconducting coil by using an ideal voltage source with a frequency of 10 Hz. Major parameters of the system are summarized in Table I and a dc filter is designed as the voltage ripple be less than 0.5 V. The ramp up rate of the current command value is set to 4 A/s and the output voltage is 45 V. Fig.4 shows the simulation results. It is found that the maximum voltage ripple is 0.15 V and the tracking error of the current is within 0.01% at the steady state.

From these results, the high accurate coil current control is demonstrated even in the 10 Hz LFAC system. We confirm that LFAC system is possible for the application of the fusion device.

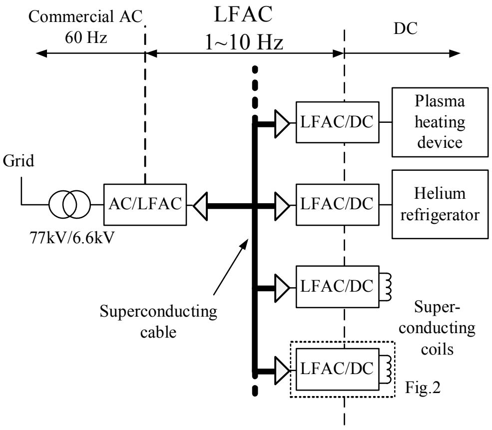

Fig. 1. An LFAC system for a fusion device

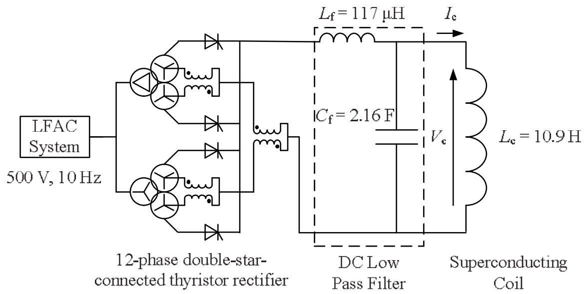

Fig. 2. Main circuit configuration of the power supply for the superconducting coil

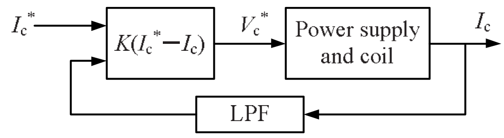

Fig. 3. Block diagram of the proportional control scheme

Table I Major parameters

Rated voltage	45 V
Rated current	6 kA
LFAC frequency	10 Hz
Proportional gain	1

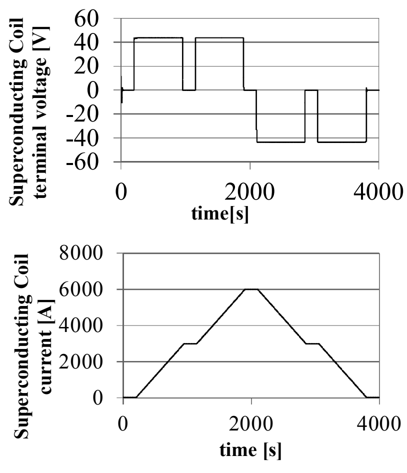

Fig. 4. Simulation results (exciting and de-exciting of coil)

[1] K. Maeba, Y. Miura and T. Ise "Power Supply System for Superconducting Coils based on Low Frequency Power Transmission", Kansai-section Joint Convention of IEE, G5-10 (2013.11)