§23. 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. In the system, ac/ac power converters convert utility frequency ac to low frequency ac (LFAC) and LFAC power is delivered to ac/dc converters near superconducting coils with superconducting cables. The advantage of LFAC system over dc system is easy fault protection due to existence of current zero crossing point and the one over utility frequency ac system is increase in current-carrying capability of cables due to reduction of cable charging current, i.e.: LFAC system has characteristics intermediate between dc and utility frequency ac systems.

LFAC system requires large-capacity ac/ac converters to convert from a utility frequency (50 or 60 Hz) to a low one (1 – 10 Hz). For this purpose, cycloconverters with thyristors conventionally are used, however they have limitation of output frequency and suffer deterioration of power factor. Back-to-back (ac/dc/ac) converters are also employed, however they have a drawback that they require current derating of semiconductor devices for a very low frequency operation. In order to overcome these drawbacks, we propose application of a Modular Matrix Converter (MMxC). Since it consists of series-connected H-bridge cells, it is suitable for high voltage application, and moreover it needs no derating of semiconductor devices because MMxC can ensure current commutation even at very low frequencies. The circuit configuration of a 7-level MMxC is shown in Fig. 1, and an example of an LFAC system for a fusion device using an MMxC is shown in Fig. 2. LFAC is converted to dc by ac/dc converter near each superconducting coil and plasma heating devices.

We newly proposed control schemes to control power flow of the MMxC and capacitor voltages of H-bridge cells. Figure 3 shows results of the numerical simulation of a 60 Hz / 1 Hz conversion operation of the MMxC using the system configuration in Fig. 1 under the condition of Table I. Sinusoidal waveforms of voltages and currents with less distortion were achieved. We also made a 1-kW MMxC composed of 9 H-bridge cells and successfully demonstrated the 60 Hz / 5 Hz conversion operation for interconnection between utility frequency ac and LFAC systems.

Optimization of the LFAC frequency and numerical simulation of the whole LFAC system are future issues.

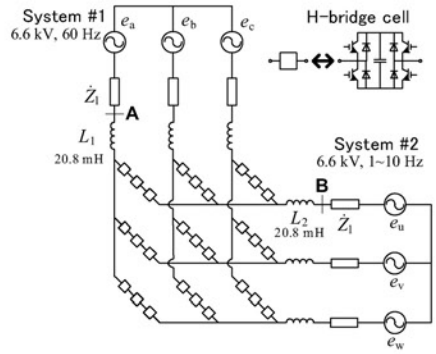

Fig. 1. A system configuration of an MMxC

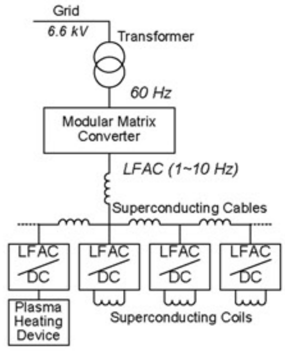

Fig. 2. An LFAC system with an MMxC

Table I Simulation condition

Rated capacity	1 MVA
Sampling frequency	3 kHz
Capacitor voltage	4 kV
Cell Capacitor	1 mF
Active power reference	1 MW (#1 → #2)
Reactive power reference	0 Mvar
Line impedance, Z_l	0.745 Ω, 5.17 mH

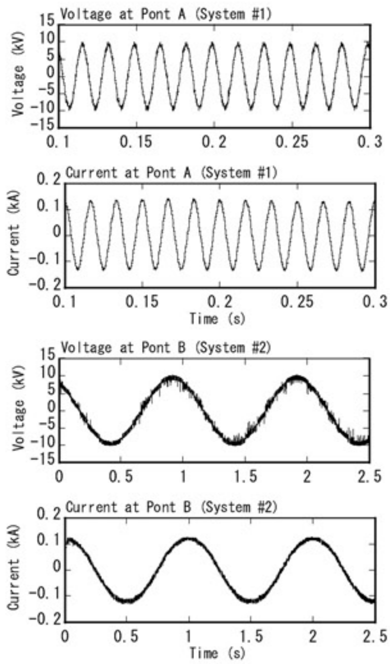

Fig. 3. Simulation results (60 Hz / 1 Hz conversion)