§4. Study on Dc Distribution for the Power System of Nuclear Fusion Systems

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Application of dc power distribution to the power system of nuclear fusion systems has been studied because a magnetic confinement type fusion reactor has many dc power components such as magnetic field coils and plasma heating devices. The dc power distribution is significantly effective to make the system efficient, simple and compact because it can connect directly dc input/output devices without ac power conversion. Additionally, introduction of superconducting cables can realize higher efficiency of the system and downsizing of bus bars. However, in case of an accident such as a ground fault, the dc system has problems of circuit protection, namely, rapid increase of a fault current due to small inductance of distribution lines and difficulty of current interruption due to inexistence of current zero points. In order to solve these problems, a dc hybrid current breaker (CB) using a superconducting fault current limiter (SFCL) is investigated.

A conventional large-capacity CB generally employs the hybrid configuration of a mechanical switch (MS) and a semiconductor CB as shown in Fig. 1. Current normally flows through the MS, and is commutated to the CB to be interrupted when an accident occurs. This configuration, however, has a drawback of increase of the fault current due to time delay of opening of the MS and securement of recovering time for avoiding of re-arcing. It results in heavy burden of the CB and increment of the number of semiconductor devices. To overcome these problems, we propose application of a hybrid CB with a SFCL[1] whose configuration is shown in Fig. 2. Employment of IGCTs (Insulated Gate Commutated Thyristors) as semiconductor switches is assumed. Normally, current flows through the MS and superconductor. In case of an accident, by the quench of the superconductor, fault current is commutated to semiconductor cells and then the MS opens without arcing. Semiconductor switches of Cell #1 are turned off and consequently current decreases due to insertion of a resistor, and finally Cell #2 interrupts current. Advantages of this system are: (i) short insulation recovery time of the MS (T_2) owing to arcless opening, and (ii) quick reclosing of the hybrid CB owing to a short duration of current-flow through the superconductor after the quench. Using the circuit in Fig. 3, numerical simulation was conducted and results are shown in Fig. 4. A peak current was reduced to 10.9 kA, which was approximately 30% compared to the case using the conventional CB. Energy consumed in the SFCL was very small and estimated at 0.22 J.

To verify operation of the proposed hybrid CB with the SFCL, experiments were conducted using the circuit shown in Fig. 5. The CB employed a superconducting coil using an YBCO wire (Super Power, I_c: 80 A, wire width: 4 mm) as a superconductor and IGBTs (Insulated Gate Bipolar Transistors) as semiconductor switches. Most of the current was successfully commutated from the MS to IGBTs due to the quench of the superconductor and sufficiently suppressed by insert of a resistor. No overvoltage across the MS was observed at the moment of current interruption. In addition, a conceptual design of a large-capacity CB with a SFCL was also conducted, and feasibility of application of the proposed CB to dc distribution system was confirmed.

1) Hara S. *et al.*: Technical meeting of IEEJ, PE-11-111, PSE-11-128 (2011).

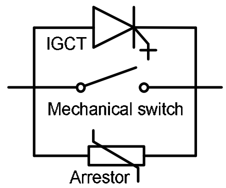

Fig. 1. Conventional hybrid circuit breaker

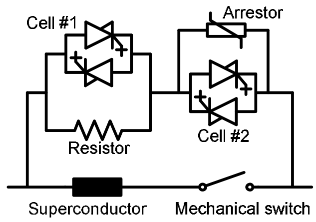

Fig. 2. Hybrid circuit breaker with SFCL

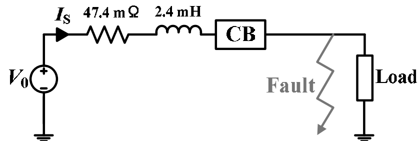

Fig. 3. Simulation circuit (V_0: 66 kV)

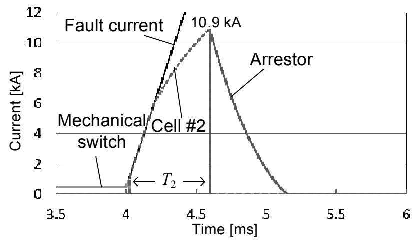

Fig. 4. Current waveform of hybrid circuit breaker with SFCL (Simulation)

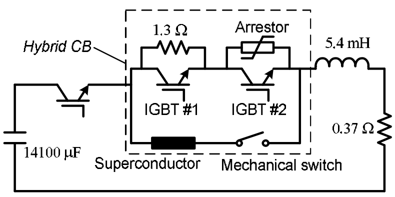

Fig. 5. Experimental circuit

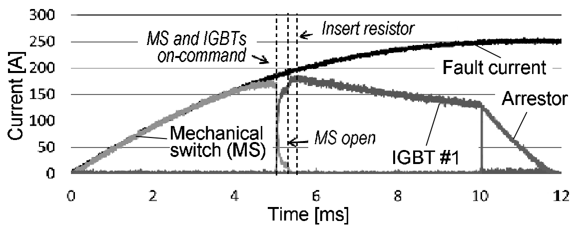

Fig. 6. Experiment result