Research on the Application of Superconducting Magnetic Energy Storage in Microgrids for Smooth-ing Power Fluctuation Caused by Operation Mode Switching

3LP6-05

Ying Xu [a,*], Yuanyuan Li[a], Li Ren[a], Jing Shi[a], Yuejin Tang[a], Lei Chen[b]

[a] *Huazhong University of Science and Technology, Wuhan 430074, China*

[b] *School of Electrical Engineering, Wuhan University, Wuhan 430072, China*

Abstract——It is widely known that the power supply would be interrupted during mode switching between grid-connected and islanded operation in a microgrid, which might lead to voltage and frequency fluctuations of the microgrid. As a power-type energy storage device, SMES (Superconducting Magnetic Energy Storage) is capable of providing rapid power response for either charge or discharge within a few milliseconds. In order to study the feasibility of applying SMES to microgrid, a microgrid model with SMES was built with Matlab / Simulink platform, and the compensation performance of SMES on the power fluctuation of microgrid was simulated and analyzed. The compensation power and current of the SMES were obtained. In this regard, a conceptual design of the SMES using high temperature superconducting (HTS) double-pancake coils composed of YBCO tape was proposed. The loss properties were evaluated based on a finite element model. The results demonstrate that HTS SMES could realize the seamless switching and provide uninterrupted power supply for the microgrid. Moreover, the energy storage system can also keep safe and stable operation during power compensation.

1. MICROGRID TOPOLOGY WITH SMES

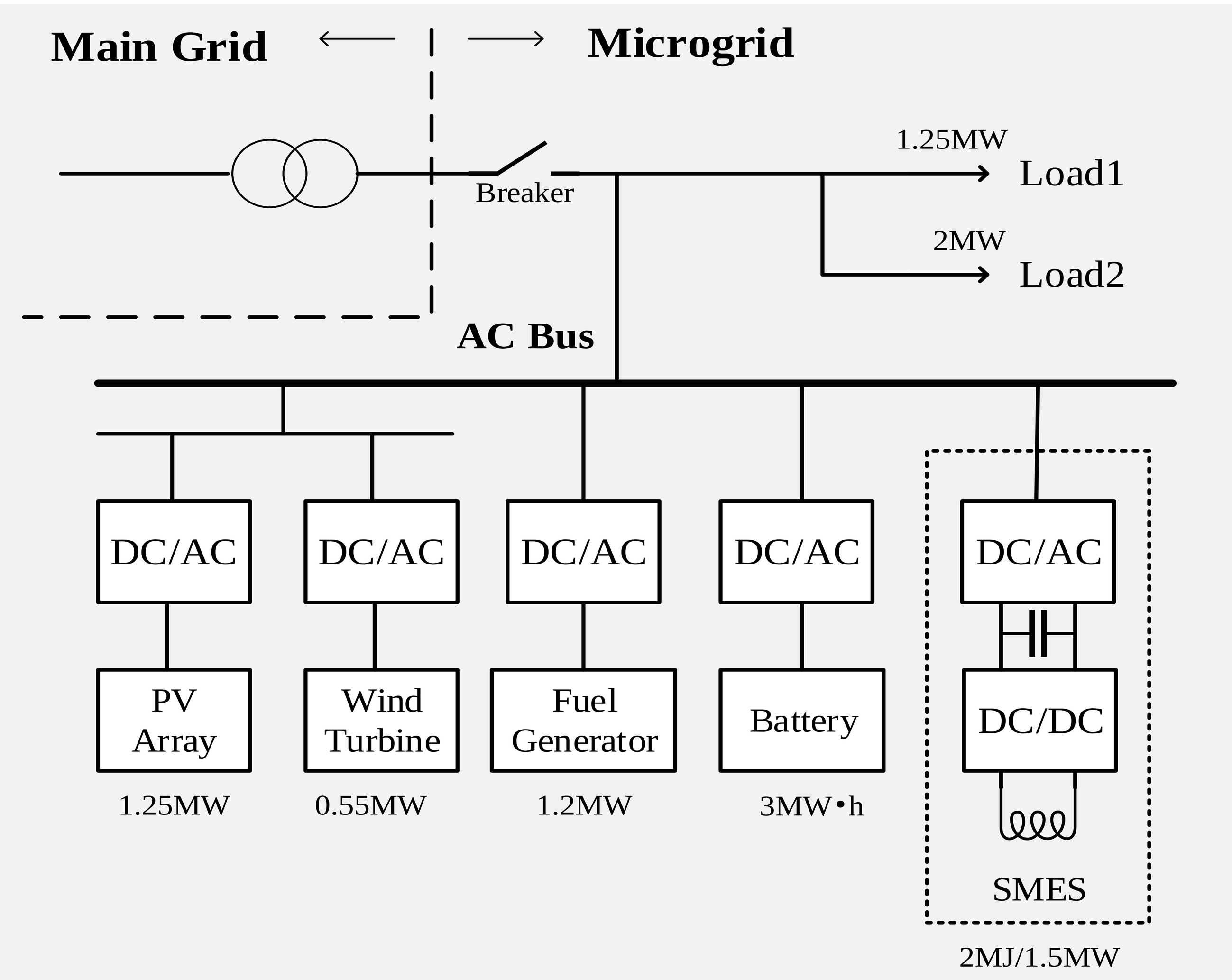

Fig. 1. Microgrid topology with SMES.

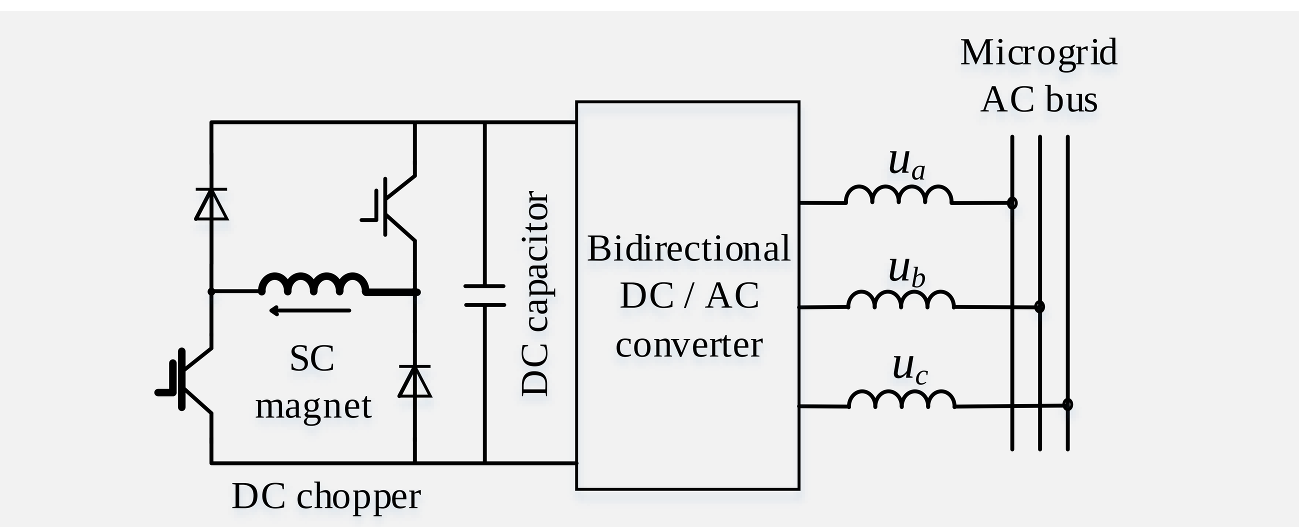

Fig. 2. Connection topology between SMES and microgrid.

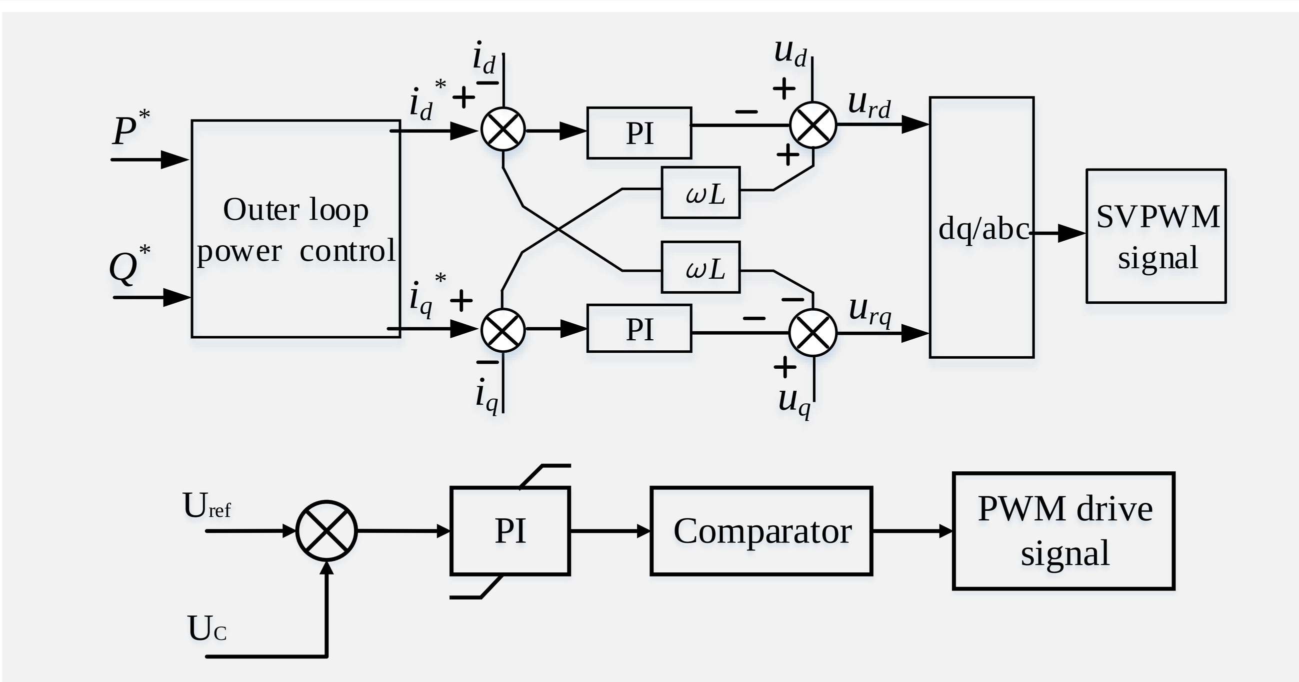

Fig. 3. Control block diagram of the VSC and the chopper.

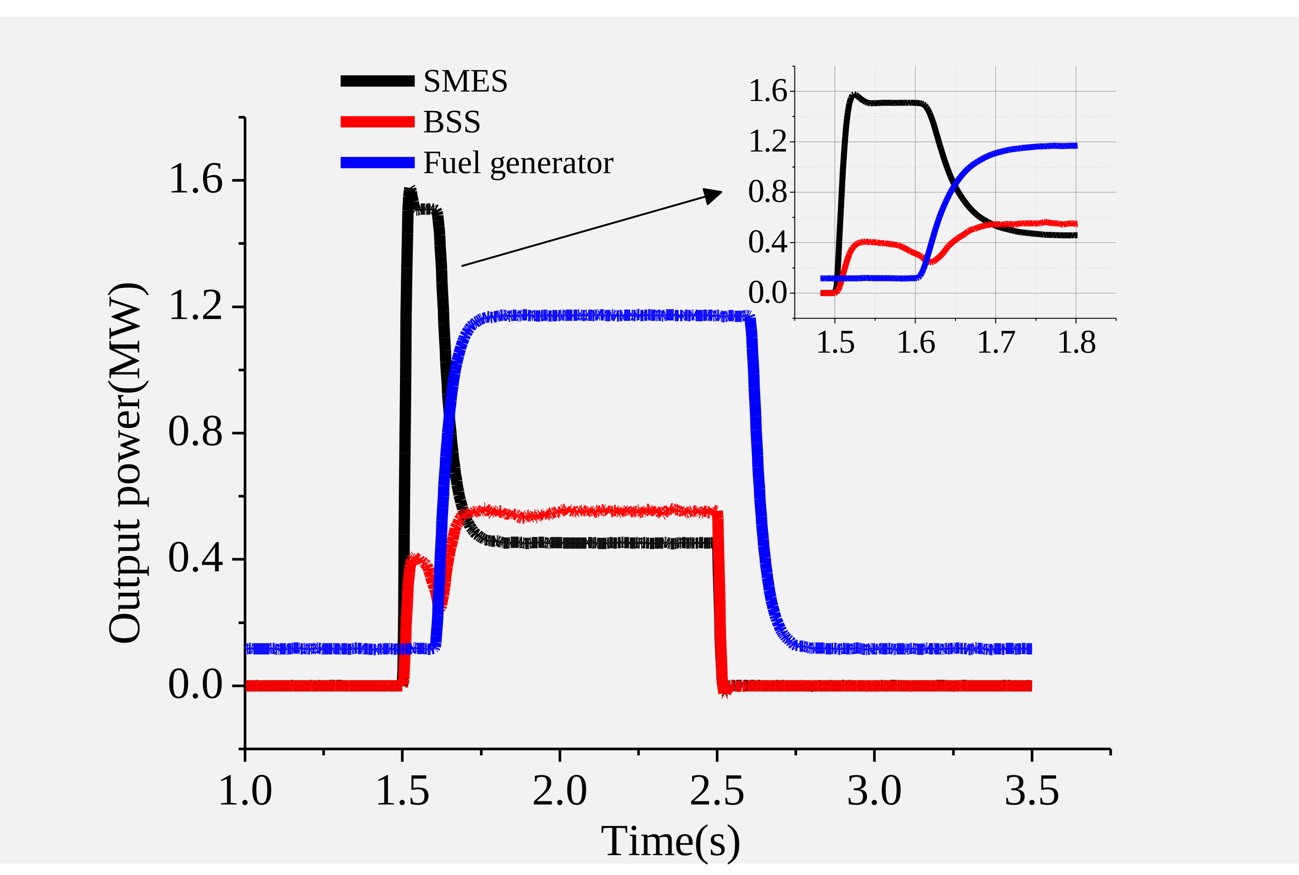

Fig. 4. Output power of the SMES, BSS and fuel generator.

1) The output power of SMES reach to 1.58 MW in 20 ms to compensate the initial high power shortage;
2) Fuel generator increases the output power to the maximum of 1.2 MW at 1.8 s;
3) BSS compensates the energy shortage in the later stage.

2. SIMULATION RESULTS

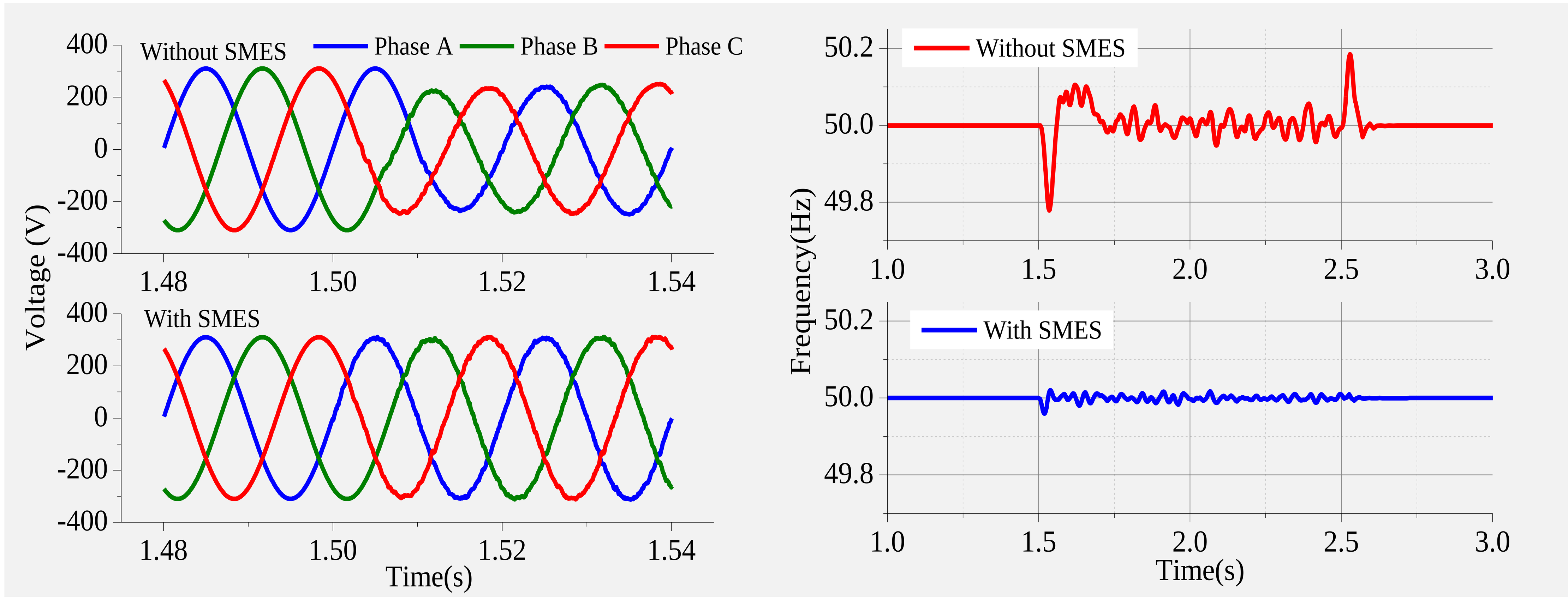

Fig. 5. AC bus voltage and frequency fluctuations of the microgrid with SMES and without SMES.

Table I Power quality analysis results of the microgrid.

Item	ΔU_{max}/V	THD	Δf_{max}/Hz
Without SMES	19.7	6.15%	0.22
With SMES	0.3	1.64%	0.04

1) The SMES could reduce the voltage fluctuation of the microgrid from 19.7 V to 0.3 V;
2) The total harmonic distortion rate also dropped to 1.64% from 6.15%;
3) The frequency fluctuation of the microgrid is also reduced from 0.22 Hz to 0.04 Hz.

3. CONCEPTUAL DESIGN OF THE SMES MAGNET

Table II Main parameters of the SMES.

Item	Value
Withstand voltage of the magnet / kV	2
Minimum operating current / A	750
Inductance / H	4
Operating temperature / K	20
Deliverable power / MW	1.6

Table III Specifications of the optimized HTS magnet scheme.

Inner radius / mm	590	B_{para} / T	5.56
Turns of a DPC	236	Operation current / A	1100
Number of DPCs	6	Inductance / H	4.09
B_{norm} / T	5.64	Stored energy / MJ	2.42
B_{perp} / T	4.78	Total length of wire / km	5.485

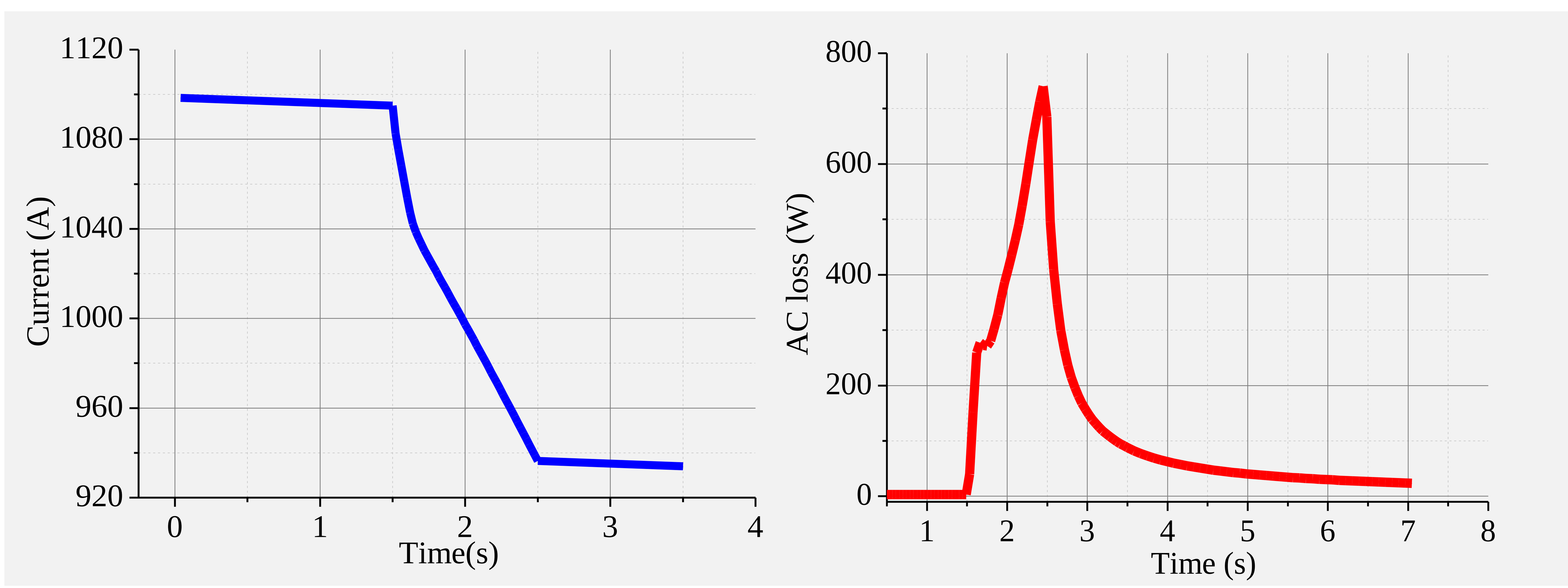

Fig. 6. Current and AC loss power of the SC magnet during the mode switching.

1) During the entire compensation process, the magnet current drops from 1095 A to 934 A;
2) The average AC loss power is 109 W for 7 seconds, and the total loss energy of the magnet is 763 J;
3) In order to remove the energy dissipation, the input power of the cooling system should be 17.44 kW (It is assumed that the input power is 160 times of its cooling power).

4. CONCLUSION

The demonstrated results draw the following conclusions:

1) The analysis results show that the SMES is able to achieve smooth switching of the microgrid, and it lays a positive effect on the improvement of the power quality of the microgrid;
2) The AC loss of the SC mangnet during the mode switching is receptible, the cooling capacity required by the magnet scheme is able to be realized.

* Corresponding author: Dr. Ying Xu. *E-mail address:* xuying@hust.edu.cn