A new concept of bridge fault current limiter-SMES for interline application to improve power quality

Zhao C.H.[1,2], Xiao L.Y.[1], Lin L.Z.[1], Yu Y.J.[1]

[1]Applied Superconductivity Lab, Inst. of Electrical Engineering, CAS, Beijing 100080, P.R.China
[2]Graduate School of CAS, Beijing 100039, P.R.China

By replacing the bias power source for bridge SFCL with the chopper for SMES, SFCL and SMES are integrated into a new concept: fault-current-limiting SMES (FCL-SMES). It can be used for interline application, when the fault appears on the feeders for common loads, SMES can absorb the incoming energy into the superconducting coil to compensate the sag to improve the power quality of the critical load. Since the current of the coil can not be charged all along, FCL-SMES can not only limit the peak current, but also the steady current. The analysis of FCL-SMES is given and the simulation validates it.

INTRODUCTION

Power quality problems are becoming more and more important these years, it is reported that they cost US manufacturers between $12 billion and $26 billion annually. Among all the problems, voltage sag and momentary outages are the most serious ones faced by industrial and commercial customers. SMES offers a solution to this problem with its many significant advantages, especially the capability to charge and discharge with very high power as compared with other power quality equipments like battery, fly-wheels and so on[1]. Furthermore, voltage sags are mainly caused by fault in distribution network, so limiting fault current also provides a solution to this problem. Some kinds of superconducting fault current limiter(SFCL) have been developed. Combined SMES and SFCL may be a new way, and various investigations and feasibility study were reported in [2]. In this paper, a new concept of fault-current-limiting SMES (FCL-SMES) for interline application is proposed, and it is analyzed and validated by the computer simulation.

BASIC PRINCIPLE OF FCL-SMES

Figure1 illustrates the configuration of FCL-SMES. For the common distribution substation, most loads are common ones, but some are critical ones which are sensitive to power quality problems caused mainly by faults in the feeders for common load. As shown in Figure1, the proposed FCL-SMES is interlined between two buses for these two kinds of loads. By replacing the bias power source for bridge SFCL with the chopper for SMES, SFCL and SMES are integrated into fault-current-limiting SMES (FCL-SMES). When fault appears on one of the feeders of common loads, the bridge SFCL can work automatically to limit the current. However, since its inherent disadvantage is that the longer the fault current limiting time, the larger the superconducting coil current. Some cycles after the fault the limiting function of SFCL is very little, so the voltage of bus decreases very much, and the severe voltage sag for the neighbor critical load is produced. Therefore, improving the fault limiting function is the first way to increase the bus voltage, reducing the compensated voltage of the sag for critical load at the same time.

During the process of fault limiting of SFCL, the superconducting coil is charged all along with rectified voltage by diode bridge. In [3] a resistor has been put to consume the energy in a three phases system to improve the function of FCL, and FCL-SMES is also based on this principle, since its chopper can work like a controlled resister r(t), absorbing the energy of the superconducting coil to compensate the sag of the bus for critical loads, as shown in Figure 2. FCL-SMES overcomes the shortcoming of common bridge SFCL. It not only can limit the fault current all the time, but at the same time compensates the sag with reduced energy needed. Thus, FCL-SMES is integrated into a promising equipment to provide a complete solution to power quality problems.

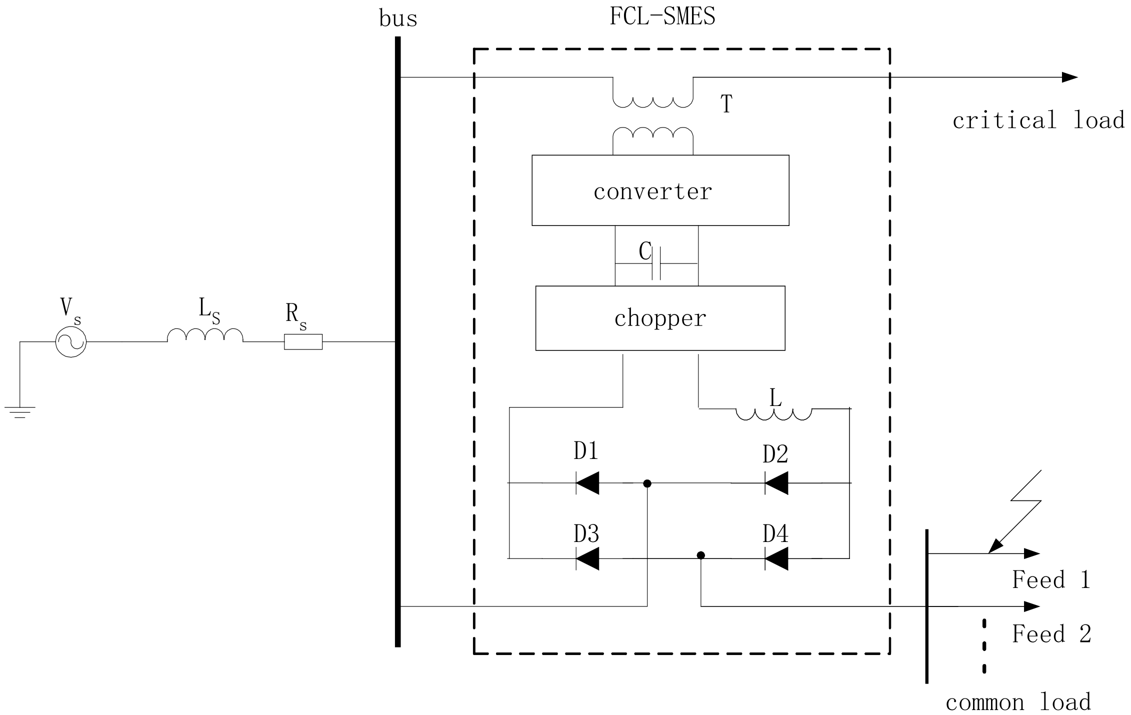


Fig. 1: Proposed configuration of bridge FCL-SMES

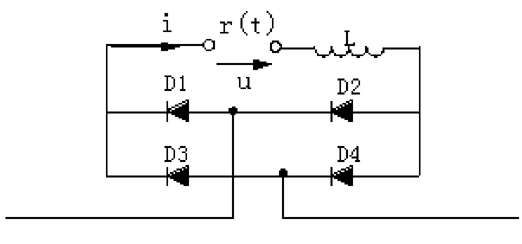


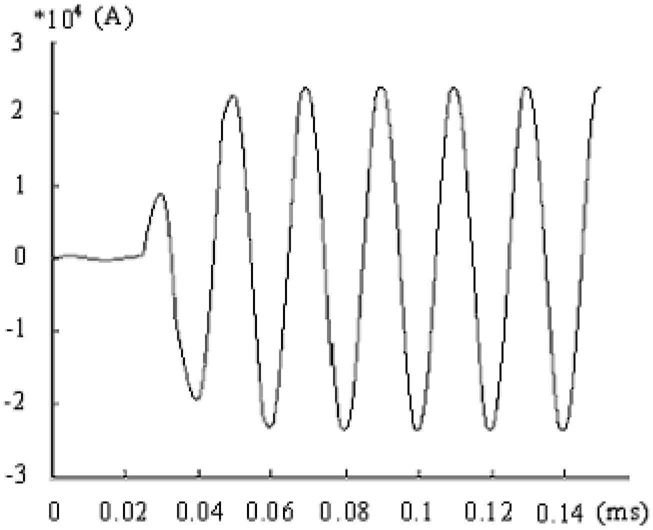
Fig.2: Principle circuit of FCL-SMES for its limiting function

Table1 Parameters of simulation for FCL-SMES

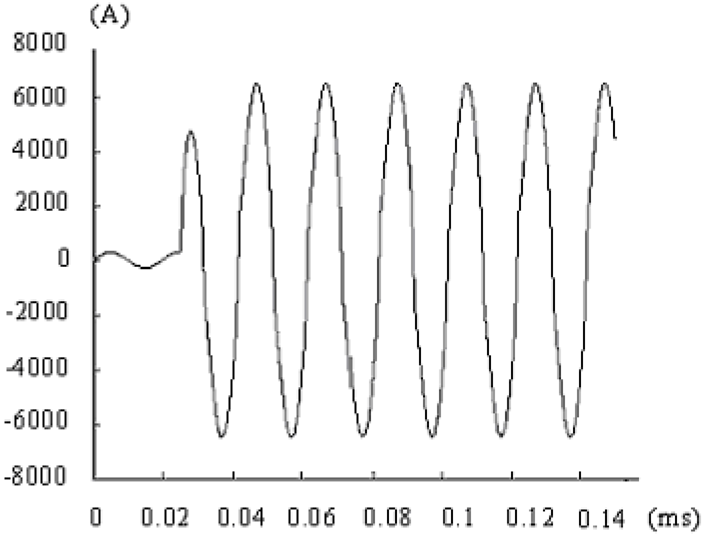
Vs: 6.06kV, 50Hz
Ls: 1.11mH, Rs: 0.01Ω ,common load: 198A(RMS)
Short circuit: 0Ω
FCL-SMES: L: 0.002H, r(t)=1Ω (0.001s after fault), ideal diode.

SIMULATION OF FCL-SMES

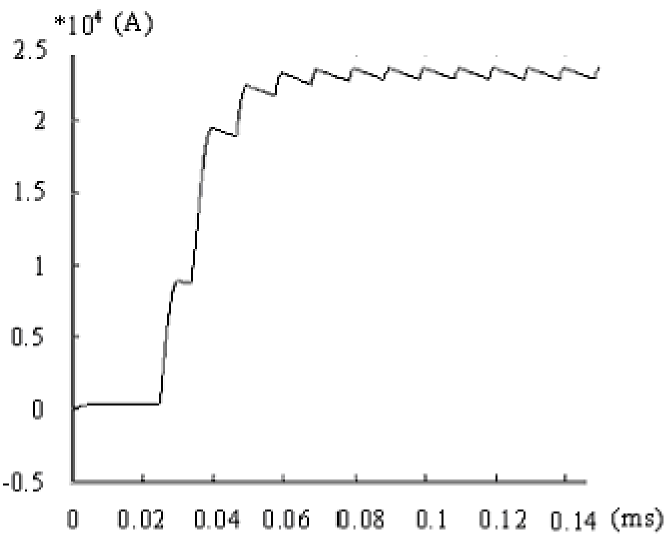
The main circuit of proposed FCL-SMES is shown in Figure 1, and Table 1 lists simulation parameters. The simulation is directed to the principle of FCL-SMES, and some assumptions are made: the compensating function, that is the discharging power, is represented by r(t) which works after 0.001s after fault; the diodes bridge is assumed to be ideal; and the critical load is neglected as compared with the fault current capacity. In Figure 3 and Figure 4, the simulation results show the principle of FCL-SMES by comparing the current and voltage between FCL-SMES and common bridge FCL. The line current of the system and the maximum current of magnet with SFCL are 25kA, but those of FCL-SMES are just 6.5kA with r(t) which equals 1 ohm and represents 16 MW discharging power for critical loads. The needed maximum coil capacity of FCL-SMES is reduced to 25% of the common FCL, and the fault current is also limited to only 26% of that. Moreover, the voltage bus of the system with FCL-SMES increases to about 0.8pu, leaving only 20% of the voltage to be compensated. That is, the energy needed for FCL-SMES is reduced to just 20% of common SMES.



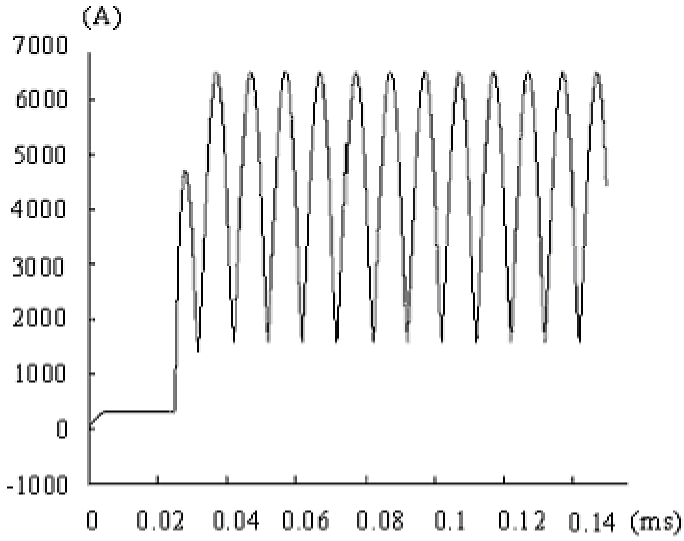
(a) Line current of the system with bridge SFCL



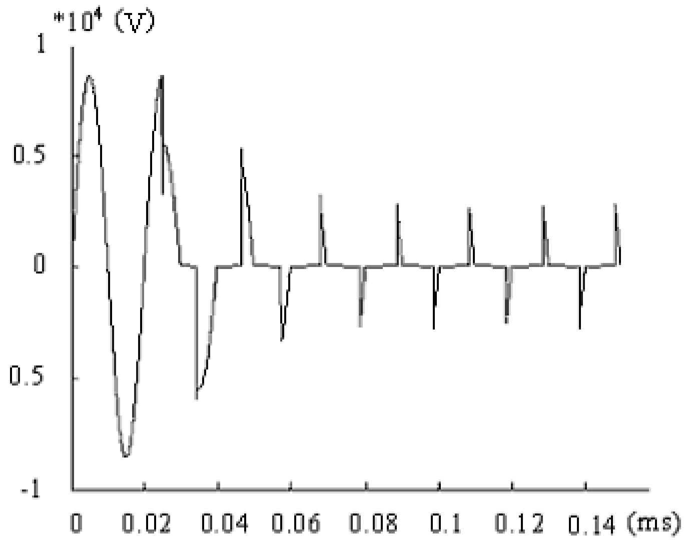
(a) Line current of the system with FCL-SMES



(b) Magnet current of bridge SFCL

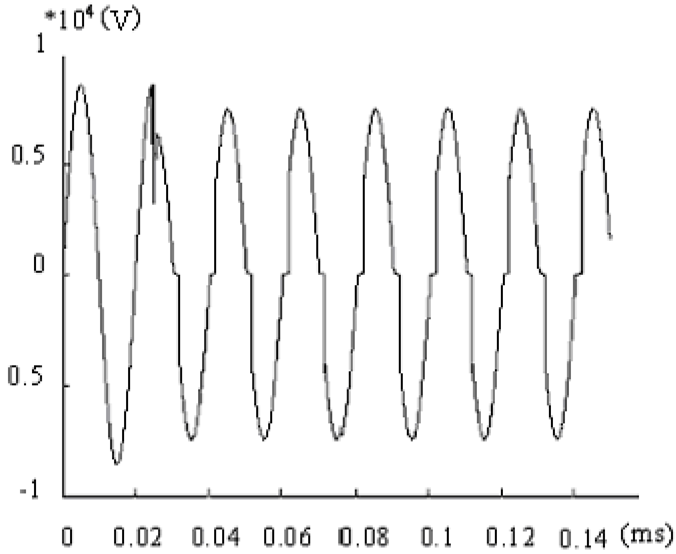


(b) Magnet current of FCL-SMES



(c) Bus voltage of the system with bridge SFCL

Fig.3: Voltage and current of the system with bridge SFCL



(c) Bus voltage of the system with FCL-SMES

Fig.4: Voltage and current of the system with SFCL-SMES

CONCLUSIONS

A new concept of FCL-SMES for interline application is proposed, analyzed, and validated by simulation. It can be a promising equipment for its performance and economical design. The contents about the mathematical model analysis, the superconducting magnet optimization, the prototype development and the experiment results of FCL-SMES, will be described in other papers.

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