Design and primary experiment for a single phase 220V/100A/6kW bridge Fault Current Limiter-SMES

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A single phase 220V/100A/6kW bridge Fault Current Limiter-SMES (FCL-SMES) demonstrator was developed. The system consists of a series linking transformer, a 6kW IGBT voltage converter with 20kHz PWM control method, a 6 kW IGBT current regulator with 20kHz phase-shifted control method, a 26mH/25A Bi-2223 coil, a rectifying diode bridge and a DSP-based controller. The current regulator can not only charge the HTS coil, but also absorb the energy from the system and the coil to compensate the voltage sags through the converter. In the controller of the system two very fast DSPs are used to implement the control algorithms for FCL-SMES.

INTRODUCTION

Bridge Fault-current-limiting SMES (FCL-SMES) has been studied in [1]. As a new equipment, FCL-SMES integrates the common diode bridge superconducting fault current limiter (SFCL) and SMES together by replacing the bias voltage source for SFCL with a new current regulator. It improves the limiting function of bridge SFCL and compensates the sags caused by the fault, reducing significantly superconducting coil capacity at the same time. A single phase 220V/100A/6kW bridge Fault Current Limiter-SMES (FCL-SMES) demonstrator was developed, and a brief description of its various subsystems, including the converter, current regulator, Bi-2223 coil, rectifying diode bridge and the DSPs-controller, is given. Some experimental results with the FCL-SMES are shown, too.

PRINCIPLE OF THE SINGLE PHASE FCL-SMES

Figure 1 shows the configuration of the single phase FCL-SMES. It is interlined between two buses for the common and critical loads respectively, and it is composed of a series linking transformer, a converter unit, a current regulator, a DC capacitor between the converter and regulator, a HTS coil, a diode bridge and a DSPs-based controller. When fault appears on one of the feeder of common loads, FCL-SMES can work automatically to limit the current all along. At the same time, the current regulator is introduced and starts to work as a controlled resister, absorbing the energy from the system and the superconducting coil itself to compensate voltage of the sag for critical load. The energy is transferred through the regulator to be controlled DC voltage for the DC capacitor, then the DC voltage of the capacitor is converted into 50Hz AC voltage, which is injected into the system through the series linking transformer to implement the voltage compensating function. So far, the fault current is limited and the problem of voltage sags is solved. The following is a brief description of the main components of FCL-SMES.

CONVERTER and ITS CONTROL SYSTEM

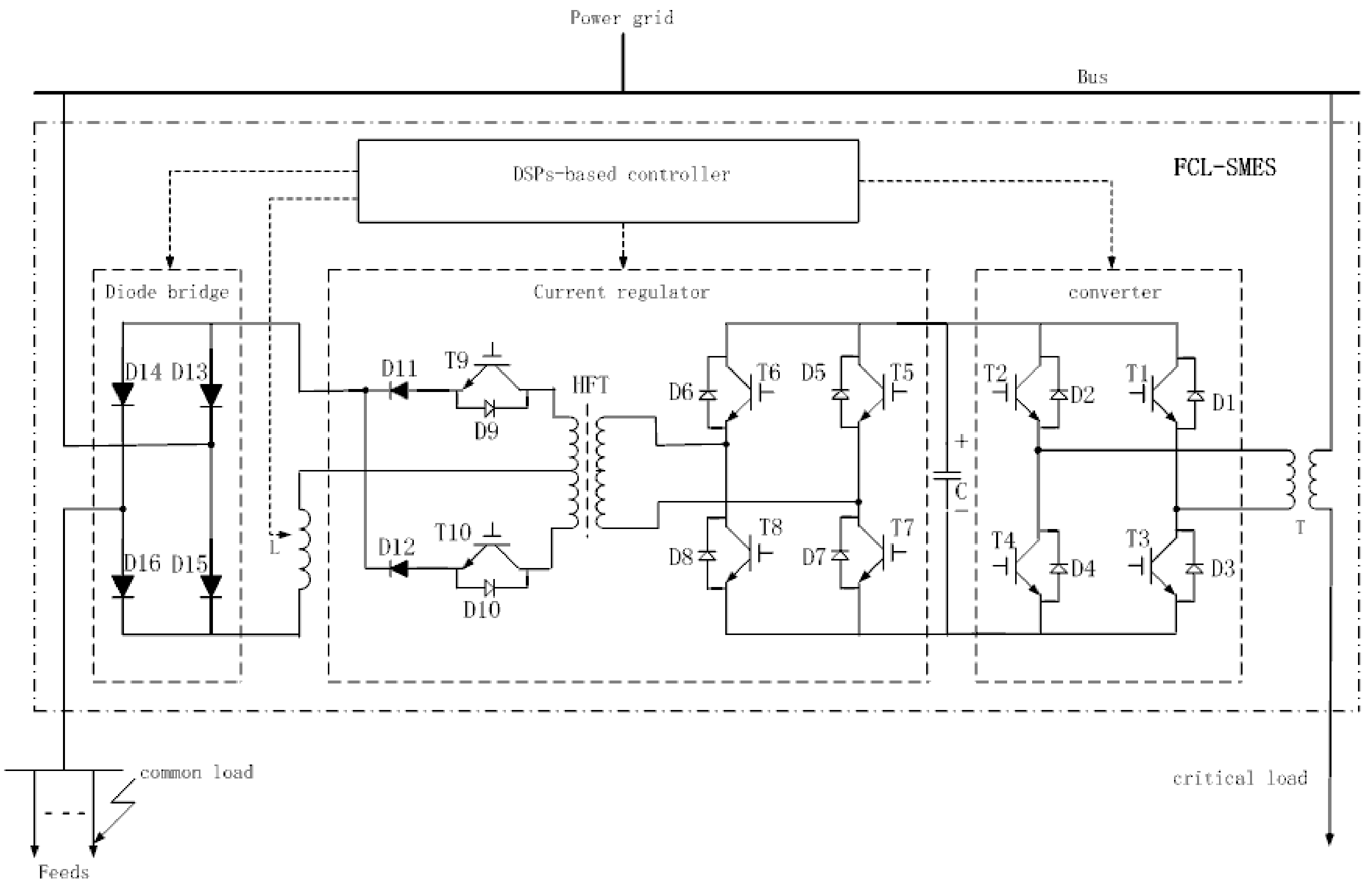


Fig.1: Main topology of the proposed single phase FCL-SMES

Table 1 Parameters of the converter and transformer for FCL-SMES

AC voltage: 0~110V (RMS)
AC Current: 60A
THD: <2%
DC voltage: 600V
Rated Power: 6kW
Transformer: 6kVA, 110/220(n=2),50Hz

Fig.2: An overview of the single phase 220V/100A/6kW bridge Fault Current Limiter-SMES

A 6kW IGBT voltage source converter (VSC) was developed to serve as the interface between the AC power network and the DC current regulator. Fig.1 shows its topology, and the single phase test is just our Phase 1 program. To improve the Total Harmonics Distortion (THD) of the AC voltage, an 20kHz SPWM (Sinusoidal Pulse Width Modulation) switching strategy and 3-Dimensional Voltage Space Vector PWM

Algorithm based on the DSP TMS320F240 are achieved [2]. The parameters of the converter and transformer are listed in Table 1.

CURRENT REGULATOR AND ITS CONTROL SYSTEM [3]

A 6kW IGBT current regulator was developed to work as the interface between the DC voltage of the converter and the superconducting coil. In fact, two equal units work in parallel. Fig.1 shows its topology. A 20kHz phase shifted control method based on DSP TMS320F2812 is adopted, and the zero current switched (ZCS) principle for the bi-directional power of the regulator is realized. In this experiment, the regulator works as a controlled resister r(t) to perform its function for FCL-SMES. R(t) is controlled to be 2.5Ω or the average power of regulator is 3.5kW. The parameters are shown in Table 2.

Table 2 Parameters of the current regulator for FCL-SMES

Input DC voltage : 600V	
Input DC: 10A	
Output DC Voltage: 0~100V	
Output DC current: 60A	
Rated Power: 6kW	
High frequency transformer:	6 kW, 20kHz, 600/60 (n=10)

DIODE BRIDEGE and HTS COIL

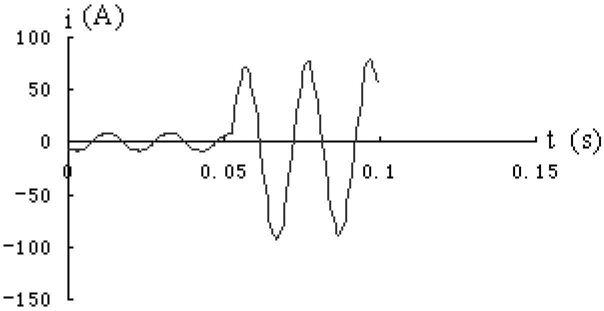
The diode bridge is a common rectifying one in Figure 1. The HTS coil was wound with Bi-2223 Ag-sheathed type from AMSC. It consists of 2 double pancakes and the total number of turns is 436, the inductance is 26mH, and the central field of the coil is 3.644×10-3T/A. During the experiment, the coil was immersed in the liquid nitrogen. The parameters in detail can be seen from [4].

EXPERIMENTS

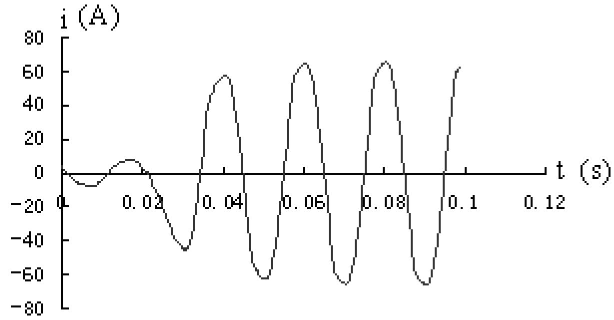
Fig.6 compares the line currents between the system with common bridge SFCL and with FCL-SMES. The peak line current with SFCL is 75A about 2 cycles after the fault, and it is the same as the one without SFCL. It is verified that the function of limiting steady current of bridge SFCL is very little, but the peak line current with FCL-SMES is still 45A after the fault. Fig.7 shows the current of the coil of bridge FCL and FCL-SMES, and they are 67A and 43A respectively. Thus, the coil capacity for FCL-SMES is reduced. Fig.8 is the voltage of the coil. It can be seen that FCL-SMES not only can limit the peak line current, but limit the steady current, especially in the case of the reduced coil capacity.

CONCLUSIONS

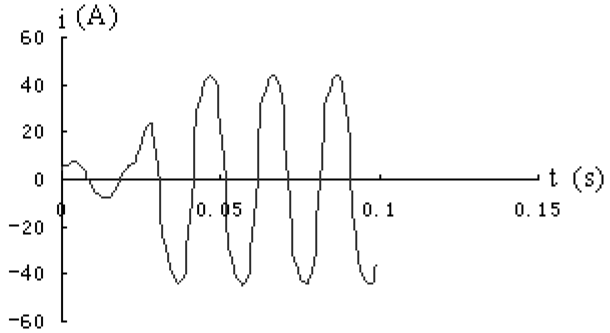
A single phase 220V/100A/6kW bridge Fault Current Limiter-SMES (FCL-SMES) demonstrator was developed, and the primary experiment was done. Its principle of the function to limit the current was verified. The components of FCL-SMES, such as converter, current regulator, the HTS coil and so on were preliminarily tested. The further experiment is underway and the stage phase II will proceed with the construction and test of a three phase prototype.



(a) Line current without SFCL and FCL-SMES

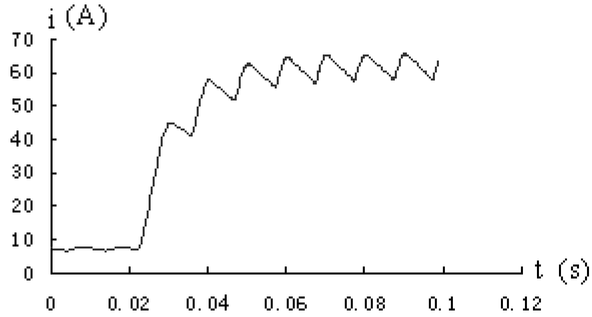


(b) Line current with bridge SFCL

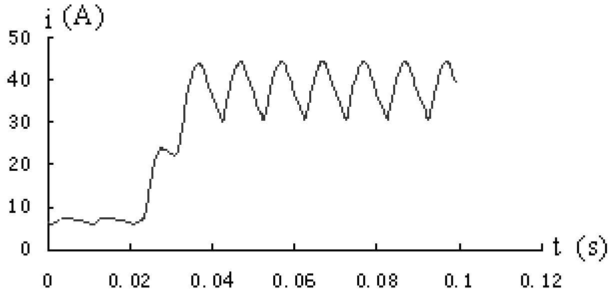


(c) Line current with FCL-SMES

Fig.6 Experiment results of line current



(a) Coil current of bridge SFCL



(b) Coil current of FCL-SMES

Fig.7 Experiment results of coil current

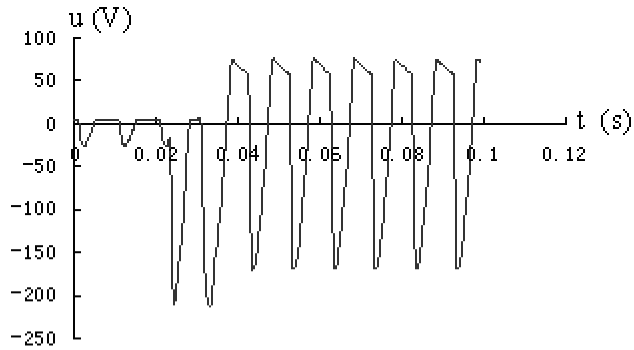


Fig.8: Coil voltage of FCL-SMES

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