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Characteristics of an HTS SMES for Solar Power System

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Abstract—**A SMES can be a perfect alternative energy storage device to the chemical batteries which are needed by most of the renewable energy supply systems. The chemical battery storage system is so expensive to maintain and causes another environmental problem because they are not recyclable. But, SMES has semi-permanent lifetime and no environmental problems cause it only need coolants which is non flammable, clean and recyclable gas. In order to verify the feasibility of a SMES for the renewable electrical power supply system, electrical characteristics of a test SMES coil with the photovoltaic power system were analyzed in this paper. Simulation results show that we can charge 40 amps of current in test SMES coil using solar power system. The experimental verification will be performed just after development of the peak power tracking system for the solar system.**

1. INTRODUCTION

Most of the present energy demand in the world is met by fossil and nuclear power plants. But the limited reserves of fuel oils and the increased interest in environmental issues had led recently to extensive research for renewable energy resources [1]. A small part of the present energy demand is met by renewable energy technologies, such as the wind, solar, biomass, geothermal and the ocean. Most of these resources have a common critical merit of cleanness themselves, but they need kind of energy storage devices such as a chemical battery to be put into the electrical power system [2]. This chemical battery storage system is so expensive to maintain itself and it also causes another environmental problem because they are not recyclable.

A SMES (superconducting magnetic energy storage) device can be a perfect alternative energy storage device to the chemical battery devices. In SMES, electricity is stored by circulating current in a superconducting coil without any losses. Because no conversion of energy to other forms is involved in the storing process, its round-trip efficiency can be very high [3]. Moreover, it has semi-permanent lifetime and no environmental problems because it only needs coolants such as liquid nitrogen which is nonflammable, clean and recyclable gas to maintain its operating temperature.

In order to verify the feasibility of a SMES devices for the renewable electrical power supply system, electrical characteristics of a SMES device with the photovoltaic power system were analyzed in this paper. An HTS (high temperature superconducting) coil as the SMES device was fabricated and amorphous silicon cells were used for photovoltaic array. Current charging simulation using bridge type converter was carried out. Simulation results show that we can charge 40 amps of current in test SMES coil using solar power system. The experimental verification will be performed just after development of the peak power tracking system for the solar system.

2. SMES COIL

The SMES system has been actively developed world widely because its benefits compared to other storage system not only as an energy storage device but also a real power control and operation in power grid [4]. Both aspects can be viewed as an application to the renewable energy supply system.

Superconductors can be classified into two types according to the operating temperature: LTS (low temperature superconductors) and HTS. In General, LTS materials such as NbTi and Nb_3Sn are cooled with liquid helium and HTS materials such as YBCO and BSCCO can be cooled with liquid nitrogen. In this paper, a single pole HTS coil was fabricated for a test SMES coil. The test coil was wound with BSCCO-2223 wire as double pancake type which is preferred in case of HTS wire whose cross section is rectangular. The specification of the HTS wire and coil is shown in Table I and Table II respectively. This coil is going to be used for charging and discharging test with a photovoltaic array and shown in Fig. 1. This coil is going to be cooled down to 77 K by liquid nitrogen and tested for photovoltaic power system with the help of some power electronic elements.

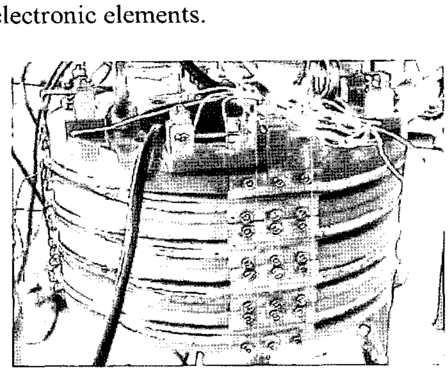

Fig. 1. Fabricated HTS double pancake coils with BSCCO-2223 wire.

TABLE I
SPECIFICATION OF THE BSCCO-2223 WIRE.

specification	value
Thickness	0.21 mm
Width	4.1 mm
Critical current density	13.5 kA/cm^2
Critical current	115 A
Max. stress	75 Mpa
Max. strain	0.15 %
Min. bending Dia.	100 mm

TABLE II
SPECIFICATION OF THE HTS DOUBLE PANCAKE COIL.

specification	value
Number of turns	56 turns
I.D. of winding	150 mm
O.D. of winding	208.24 mm
Height of winding	88 mm
Number of pancake	4
Total length of HTS wire	252 m
Inductance	29.2 mH

3. PHOTOVOLTAIC ARRAY

As an electrical power source for charging SMES coil, a photovoltaic array was used. Amorphous silicon cell which has a rather low efficiency but is much cheaper compared to the single grain crystal arrangement were used for the photovoltaic array. Fig. 2 shows the photovoltaic array which is going to be used as an electrical power source to charge the HTS SMES coil and the specification of this array is listed in Table III. The two most important parameters widely used for describing the electrical performance of the cell are the open-circuit voltage and the short-circuit current. With these parameters, an equivalent electrical circuit of photovoltaic module can be shown with a diode and ground leakage currents like Fig. 3.

The electric characteristics of the photovoltaic cell are generally represented by the current versus voltage curve. Fig. 4 shows i-v characteristic curve of the photovoltaic array shown in Fig. 2 under the condition in sunlight. The power output of the panel is the product of the voltage and the current outputs, so the maximum power is produced at voltage corresponding to the knee point of i-v curve which is shown in Fig. 4. In order to maintain the maximum power output, there should be a peak power tracking controls which actually control the duty ratio of the switching devices interfaced to the SMES coil [5, 6]. This control unit is under development now.

TABLE III
SPECIFICATION OF THE PHOTOVOLTAIC ARRAY.

specification	value
Maximum power	53 W
Open circuit voltage	21.4 V
Short circuit current	3.3 A
Dimension	986 x 451 x 40
Connection	36 series

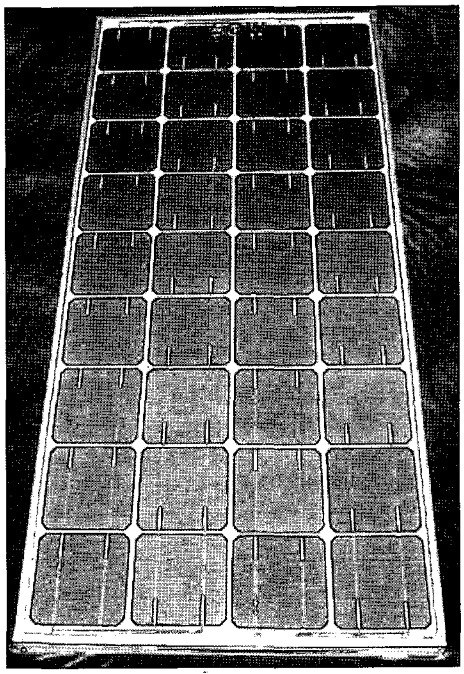

Fig. 2. 53 W Photovoltaic array with 36 connected series cell.

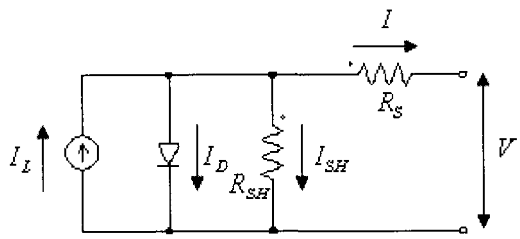

Fig. 3. An equivalent electrical circuit of photovoltaic module with a diode and ground leakage currents.

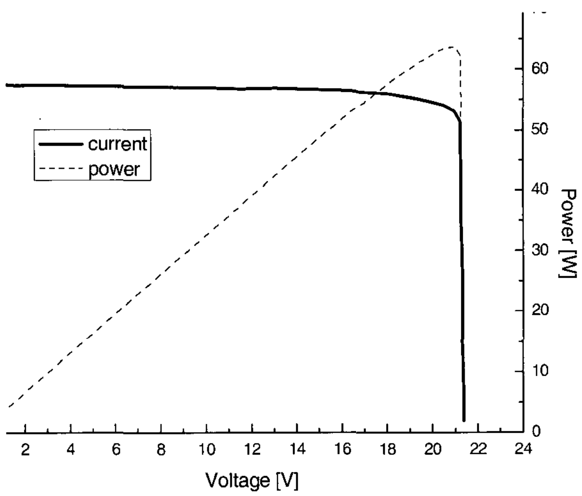

Fig. 4. i-v characteristic curve of the photovoltaic array shown in fig. 2.

4. PV POWER SYSTEM

The stored energy density is very high in SMES because a superconducting wire can carry very large current without any electrical loss compared to that of a conventional wire. But general current output of a photovoltaic cell is limited to relatively low current, so a switching power electronic device should make an interface between the source device and the storage device or SMES coil. It can also control the charging and discharging time which is important to the stability of the SMES coil. Fig. 5 shows a power electronic switching circuit for the driving the HTS SMES and the simulation results of current charging characteristics are shown in Fig. 6.

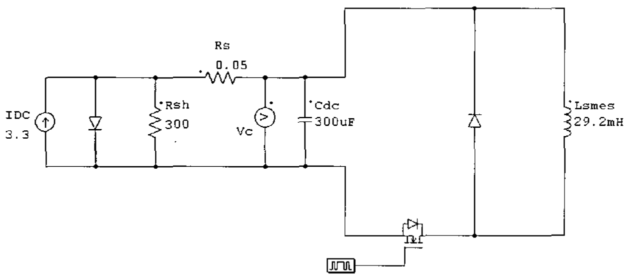

Fig. 5. Driving circuit for the charging test of the SMES coil.

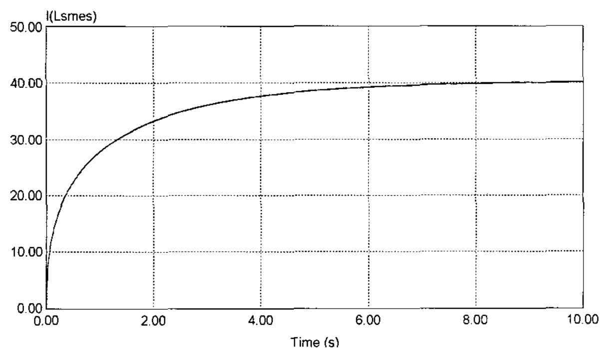

Fig. 6. Current charging characteristics of the test HTS SMES coil.

5. RESULTS AND CONCLUSION

Simulation results show that we can charge 40 amps of current in test SMES coil using solar power system. The experimental verification will be performed just after development of the peak power tracking system for the solar system. The SMES coil can be used as power conditioning device for a small scale power system as well as just a storage device. The SMES device is a clean device which does not use any anti-environmental materials so it can be a perfect alternative energy storage device to the conventional chemical battery for the renewable energy resource system.

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