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Power Quality Enhancement using Superconducting Magnetic Energy Storage System

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ABSTRACT
In the past few decades, the integration of Renewable Energy Systems in the distribution side of a main grid has increased to a substantial level. But it necessitated the introduction of Energy storage systems simultaneously. In view of this, SMES is the novel approach that stores excess electricity from the grid within the magnetic field of a superconducting coil with near-zero loss of energy. This technology has proven to be matured as it improves the power quality in addition to damping the swings on grid network. It also does the function of load leveling & it is environment friendly too.

Keywords – Energy storage, Cryostat, Power Quality,

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I. INTRODUCTION

As it is a high time for Energy storage systems, SMES system proves to be a promising approach as compared to other storage systems. A general SMES system comprises of a superconducting coil placed in a cryostat, a power converter unit and an control unit. SMES is a grid-enabling device that stores and discharges large quantities of power almost instantaneously. The system is capable of releasing high levels of power within a fraction of a cycle to replace a sudden loss or dip in line power. Strategic injection of brief bursts of power can play a crucial role in maintaining grid reliability especially with today's increasingly congested power lines and the high penetration of renewable energy sources, such as wind and solar. In this paper, a matlab model of a SMES system connected to grid has been introduced

I. SUPERCONDUCTIVITY

The Superconductivity is a phenomenon in which the resistance of the material to the electric current flow is zero. When resistance falls to zero, a current can circulate inside the material without any dissipation of energy. Energy storage in a normal inductor or in a coil is not possible due to the ohmic resistance of the coil. The ohmic resistance can be removed from the coil by lowering the temperature of the conductor. The temperature below which the coil offers superconductivity is known as the Critical Temperature. Its value is different for different elements. TABLE 1.1 provides the values of critical temperatures for different elements.

Element	Critical Temperature
Uranium	0.2 K
Titanium	0.4 K
Cadmium	0.517 K
Zinc	0.85 K
Aluminum	1.175 K
Indium	3.41 K
Tin	3.72 K
Mercury	4.15 K
Lead	7.196 K
Niobium	9.3 K

TABLE 1.1 Different Elements & Their Critical Cryogenic Temperatures

II. SMES SYSTEM

Figure 2.1 represents a general electric grid with SMES system. A superconducting coil is placed in a vacuum-insulated vessel in which cryogenic temperatures are maintained. A DC current is circulated through the superconducting coil so that the inductive reactance of a coil also becomes zero and hence the magnetic field doesn't tend to decay after a specific time. In order to convert AC supply to DC one, a power conditioning unit is placed between AC grid and Cryostat in which a coil is placed. A VSC based inverter can be used along with dc-dc converter for regulating the charge-discharge of a coil. A controller is necessary to measure various quantities in system and generate suitable gate pulses for pwm control of a bidirectional converter.

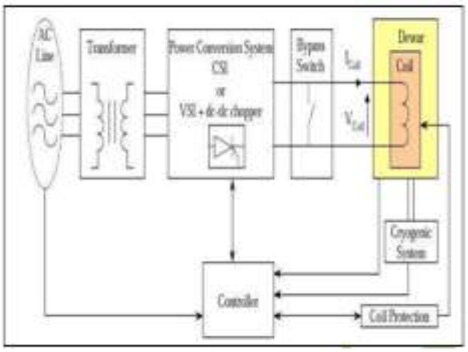

FIGURE 2.1 Block Diagram of SMES System

III. MODES OF A SMES SYSTEM

In general, the operation of a SMES system can be explained with three modes. Mode 1 is a charging mode which occurs when generation in main grid is greater than the load demand. In this mode, the excess electric energy is bypassed to SMES system by converting it to DC. The circulating DC current produces a stationary magnetic field within which the energy is stored. This energy can be given as $0.5LI^2$. Mode 2 is Stand-by mode. In this mode both generation & demand are same and hence the bypass switch connected across coil is closed & the current keeps on circulating in the loop only. Mode 3 is discharging mode. In this mode demand is greater than generation. Hence, the deficient power is supplied by SMES by converting it back to AC supply. The bypass switch is opened in this mode.

IV. SIMULATION MODEL

FIGURE 4.1 shows a matlab Simulink model for a SMES system connected to an electrical grid having following parameters-
Source Voltage-
Load Voltage-
Space Vector PWM control technique has been used for regulating the inverter's output. A three phase fault is created during the time interval of 0.5 to 0.7 seconds.

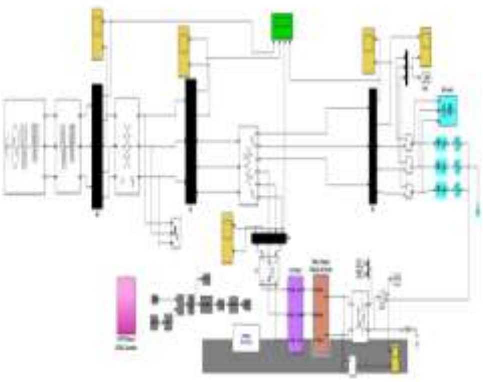

FIGURE 4.1 Matlab Simulink Model of SMES System connected to an Electrical Grid

V. SIMULATION RESULTS

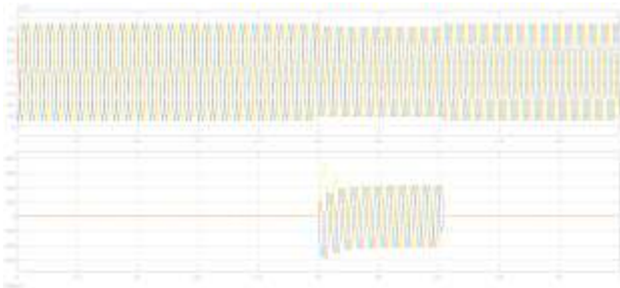

FIGURE 5.1 Source Voltage & Source Current

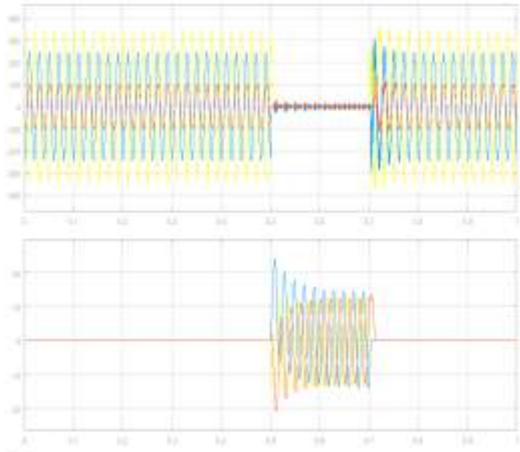

FIGURE 5.2 SMES Injected Voltage & Current

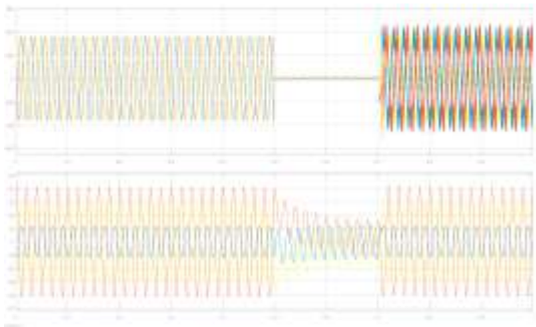

FIGURE 5.3 Uncomensated Load Voltage & Current

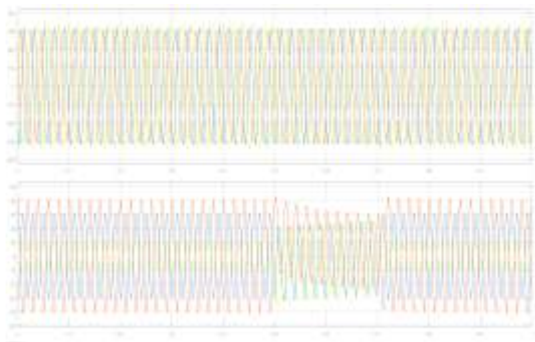

FIGURE 5.4 Comensated Load Voltage & Current

II. CONCLUSION

Nowadays, it is very much important to do the optimum use of renewable energy sources. So, the solution for an efficient way of doing the optimum use of these sources is the SMES system with hybrid energy sources. Also, instead of using IGBT in VSC we can prefer to IGCT. Both the characteristics of IGBT and GTO are present in IGCT, so use the IGCT as a switch for controlling the power flow. There are some more advantages of CSC SMES technology over VSC technology i.e less ripple contents, less THD, no complex circuitry is required for control circuit, DC/DC converter is not required. From the above theory, it is concluded that SMES is the versatile technology in view of the current power scenario.

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