Comparative Study of with and without Solar IGBT as a Switch in SMES System for High-Power DC Application

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Abstract— A superconducting Magnetic Energy Storage (SMES) system includes a high inducting coil that can act as a constant source of direct current. A high temperature SMES (HTS) unit connected to a power system is able to absorb and store both active and reactive power from this system and to release these powers into this system in the demand periods. These injected powers can be controlled by adjusting the power conversion system of SMES by changing both the duty cycle of the dc-dc chopper switches and its operation modes. In this paper, an efficient design based on an SMES unit controlled by the combined the artificial neural network (ANN) and adaptive control method is presented to improve transient stability by regulating the dc link voltage and to damp and reduce the voltage and frequency fluctuations that are always associated with solar power generation. The system behavior is tested with three different faults/events for both voltage and frequency fluctuations of solar power supply with and without applying the SMES unit. The results show that both voltage and frequency stabilities are significantly increased when the SMES unit is applied in these three events.

Keywords: Superconducting Magnetic Energy Storage (SMES), Power Quality, Smart Generation

I. INTRODUCTION

Major stability problems occurs in the power system is due to- Disturbances in power generation and distribution systems, Rapid growth in loads and The sensitivity of many power system devices. Also disturbances and short outages in generators or transmission lines create various adverse effects. A range of storage technologies are in the marketplace but the most practicable are Battery energy storage systems(BESS), Superconducting magnetic energy storage (SMES) systems, Pumped storage hydroelectric systems, etc. BESS include restricted life cycle, voltage and current margins, and probable environmental hazards.

The SMES system consists of – A large superconducting storage coil, Cooling system and An AC to DC power converter system, classically called power conditioning system. Some of its attributes provide substantial advantages over on other storage technologies i.e, Very high storage efficiency (about 98%). Release large amounts of stored energy very rapidly. More reliability.

In addition, the number of charging and discharging cycles in SMES is unlimited. Appropriate control of its power converters system can adjust the active and reactive power absorbed from or delivered to power systems.

A. *Super Conductivity:-*

It is a phenomenon of exactly zero Electrical Resistance, when cooled below a characteristic critical temperature. The electrical resistance of a metallic conductor decreases gradually as temperature is lowered. In ordinary conductors, this decrease is limited by impurities and other defects.

Physical properties of superconductors vary from material to material, Such as the heat capacity and the critical temperature, Critical field, and Critical current density at which superconductivity is destroyed.

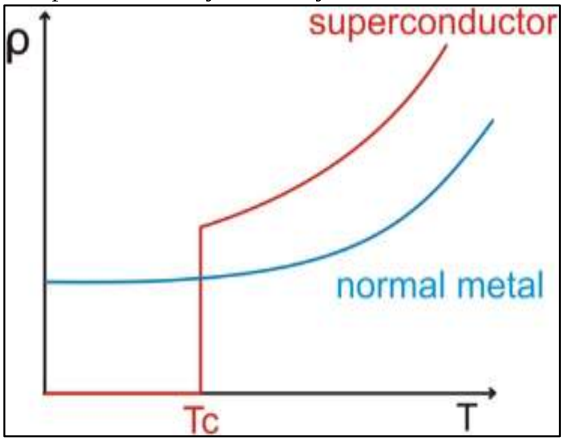

Fig. 2.1: Characteristics Diagram of Super conductivity

II. SUPERCONDUCTING MAGNETIC ENERGY STORAGE (SMES)

A. *Superconducting Magnetic Energy Storage (SMES)*

In the magnetic field created by the flow of direct current in a superconducting coil cryogenically cooled to a temperature below its superconducting critical temperature. It is an energy storage system that stores energy In the form of dc electricity by passing current through the superconductor. It has the energy in the form of a dc magnetic field. The conductor for carrying the current operates At cryogenic temperatures and becomes superconductor Virtually no resistive losses as it produces the magnetic field Once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored infinitely. The stored energy can be released back to the network by discharging the coil. The magnetic field is created by flow of direct current through the coil. In this state the current in a coil can flow for infinite time. This can also be seen from the time constant of a coil $\tau = L/R$, *when* R goes to zero and τ then goes to infinity. SMES systems are highly efficient, i.e. greater than 98%.

A typical SMES system includes three parts:

1) Superconducting coil,
2) Power conditioning system and
3) Cryogenically cooled refrigerator.

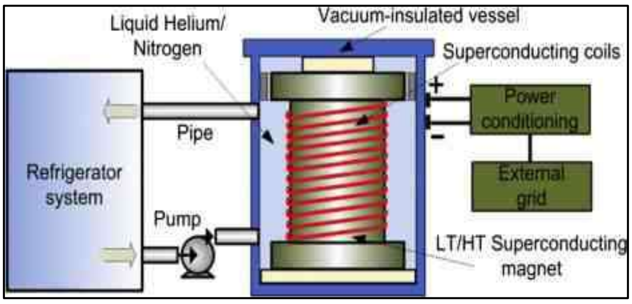

Fig. 3.1: Schematic diagram of SMES system

B. Superconducting Coil

1) Main part of a SMES system

Most superconducting coils are wound using conductors comprised of many fine filaments of a niobium-titanium (NbTi) alloy embedded in a copper matrix. The Size of the coil depends upon The energy storage requirement Coil geometry.

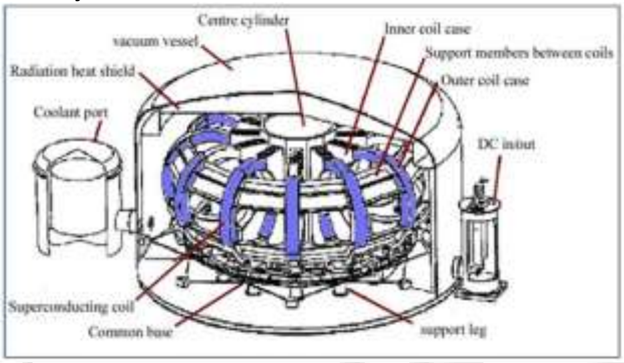

Fig. 3.2: Main Parts of SMES System

C. Power Conditioning System

The power conditioning system uses an inverter/ rectifier to transform alternating current (AC) power to direct current or convert DC back to AC power.

An ac/dc PCS is used for two purposes:

1) One is to convert electric energy from ac to dc.
2) The other is to charge and discharge the coil.

Three configurations available:

1) Thyristor based PCS.
2) Voltage source converter based PCS.
3) Current source converter based PCS.

D. Cryogenic Unit

The SMES coil must be maintained at a temperature sufficiently low to maintain a superconducting state.

Reaching and maintaining this temperature is accomplished by a special cryogenic refrigerator that uses helium as the coolant or liquid nitrogen.

The refrigerator consists of one or more compressors for gaseous helium and a vacuum enclosure called a “cold-box”.

Helium can be used as the so called "working fluid" in such a refrigerator because it is the only material that is not a solid at these temperatures.

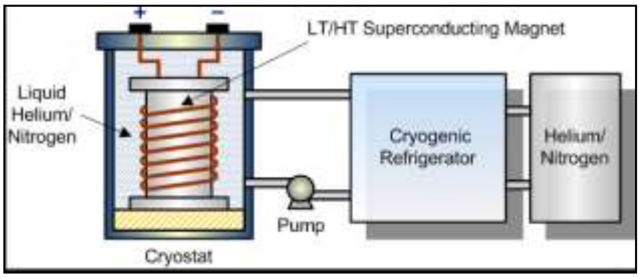

Fig. 4.1: Cryogenic Unit

E. Monitoring and Contol System

It establishes a link between power demands and power flow, to and from the SMES coil. Receives dispatch signals from the power source and status of the coil. Maintains system safety and sends system status information to the operator. It realize early-warning and prediction by data analysis, processing and optimization. Modern systems are tied to the internet to provide remote observation and control.

F. Operational Analysis of SMES

The operation of SMES is based on the fact that the superconducting coil is charged with magnetic energy so that the current will continue to flow in superconductor even after the voltage across it has been removed. A superconducting coil that is cooled below its critical superconducting temperature has negligible (zero) resistance. Thus the current will continue to flow in it.

The stored energy is inductive: $E = \frac{1}{2} LI^2$

There are three different modes of operations of the SMES coil:

1) Charging mode
2) Stand-by/ freewheeling mode
3) Discharging mode

G. Charging Mode

At first switch S is closed and 1load is connected across the source. In Energy Charging state switch – S- close, K1 - close, K2- close. After Closing switch K1 and K2, Coil start charging. The Charging equation of the coil is gives as

$$U - L\frac{dI(t)}{dt} - I(t)R_e = 0$$

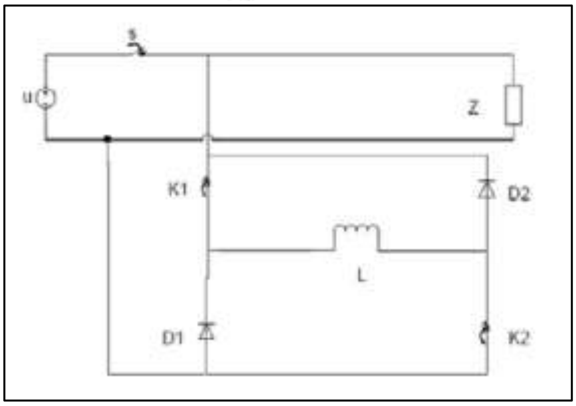

Fig. 4.4: Charging Mode

H. Free Wheeling Mode

Switch S and K2 is closed and Switch K1 is open. In this mode of operation load is directly connected to source and current flow in given direction. In superconducting coil also

Current flows in given direction because its is charged and there is no Resistance in it. SC coil can store charge for infinite time.

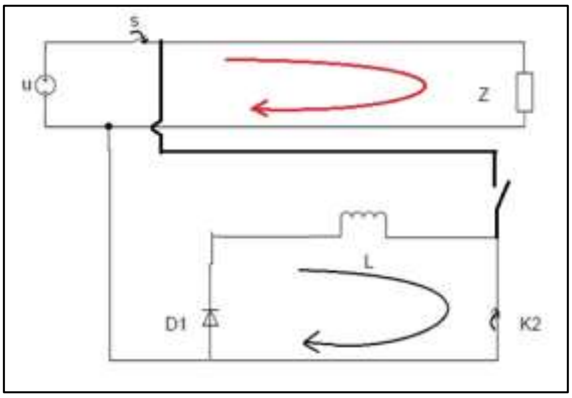

Fig. 4.5: Free wheeling Mode

I. Discharging Mode:

In this mode of operation discharging of the energy stored into SC coil occurs. If due to any disturbance source disconnected from the load then at that moment SC coil start discharging.

Here, SC coil provide continues power supply to the load In this mode, switch S-open (due to any disturbance), then K1 and K2 also get open to prove power to the load.

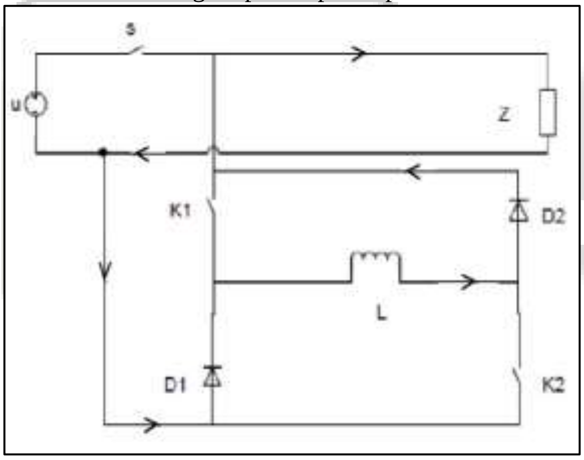

Fig. 4.6: Discharging Mode

III. SIMULATION AND RESULT

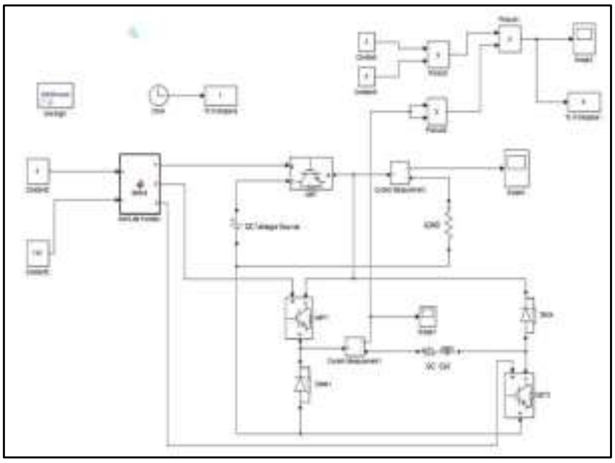

Fig. 5.1: Matlab simulation diagram proposed DC SMES System for high voltage Operation

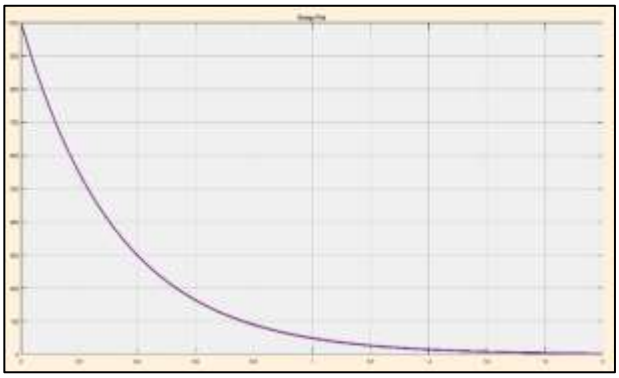

Fig. 5.1.1: Simulation result for proposed DC SMES using IGBT Energy Plot

Fig. 5.1.2: Simulation Result for Proposed DC SMES using IGBT Current Plot

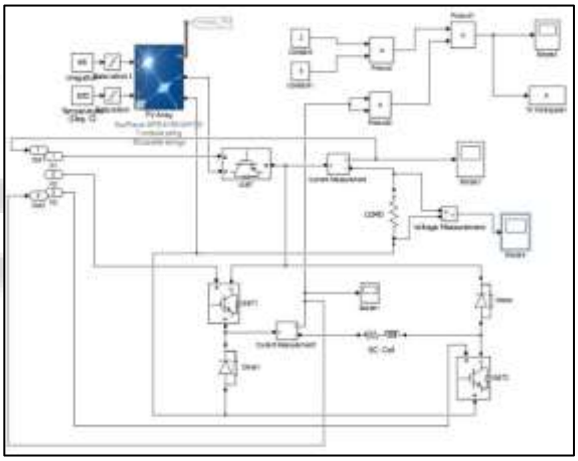

Fig. 5.2: Matlab Simulation with connected to the Solar as a (SMES) IGBT

A. Simulation and Result

Fig. 5.2.1: Simulation result with solar Connectd to SMES Energy Plot

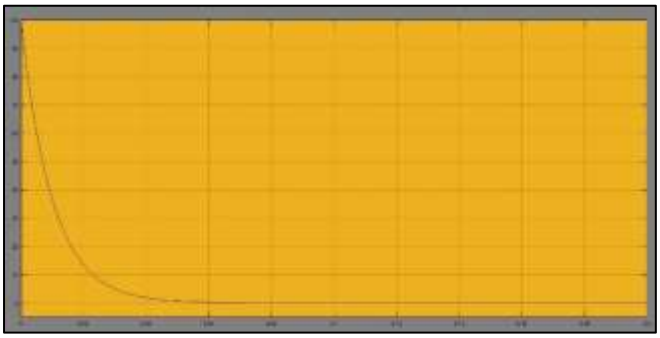

Fig. 5.2.2: Simulation result with solar Connectd to SMES Current Plot

IV. RESULTS AND DISCUSSION

A. *Discussion:*

The model proposes a method to link the superconducting inductance to the Matlab function to design and implement a controlled SMES.

Through this construction, it has been found that the superconducting inductor is very energy efficient and receives the energy for the discharge purpose.

V. CONCLUSION

This work provides an overview and comparative study of the SMES system using IGBT and MOSFET. This mathematical model of integrated SMES was proposed and developed with the simulated results, which shows – Variation in result with variation of coil material. Response of SMES also vary with switching device.

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