Analysis and Simulation of SMES System with Hybrid Connected Solar System in High-Power DC Application

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Abstract: Energy storage systems are the recommend potential solutions for enhancing efficiency and power quality. It can also increase the reliability of power grid with significant penetrations of renewable energy. This paper explains the significant developments and research works of SMES system which is hybrid connected with the PV array. These devices have a very fast response time and are appropriate for applications with rapid charge and discharge requirements. For large DC application (such as heavy load lifting, rolling machines etc) we need a reliable source with backup mechanism for smooth operation. A SMES unit connected to a solar system is able to absorb and store power from this system and to inject these powers into this system when they are needed. Here, This paper provides an overview and preliminary study of the design of superconducting magnetic energy storage (SMES) systems with solar(PV) system which is based on renewable source with improved reliability.

Keywords: SMES, Controller, Power Conditioning System (PCS), Cryostat, electromagnetic Energy, PV array.

I. INTRODUCTION

Electrical energy is one of the most significant sources of energy that science has given to mankind. It has also turn into a element of modern life and one cannot imagine of a world without it. Electricity has many uses in our day to day life. Over recent decades, energy storage technologies have enhanced and provided significant economic and environmental benefits. In addition, Energy storage is an essential element of a renewable energy system. Even a traditional thermal or hydro based energy grid has need for ready storage. Storage systems can generate revenue in a variety of ways including matching supply with demand timing, power conditioning, avoiding expenses from more costly sources.

Apart from this, Energy storage is an essential part of power system to improve power system stability Efficiency and reactive power balance in the power system. Even a conventional thermal or hydro based energy grid has need for ready storage. Storage systems can generate revenue in a variety of ways including matching supply with demand timing, power conditioning, avoiding costs from more expensive sources.

We have to a secure, reliable electricity supply 24*7. We also need to make more use of renewable energy resources, such as solar and wind, to reduce our reliance on non-renewable fossil fuels such as oil and gas. But, it's not so easy to just switch over to using solar and wind for all our energy needs. In recent times more renewable power sources are coupled in low voltage distribution systems or as micro grids.

The superconductive energy storage (SMES) is one of the most helpful technique to supply energy to the load. It can give a large power in a short time to load.

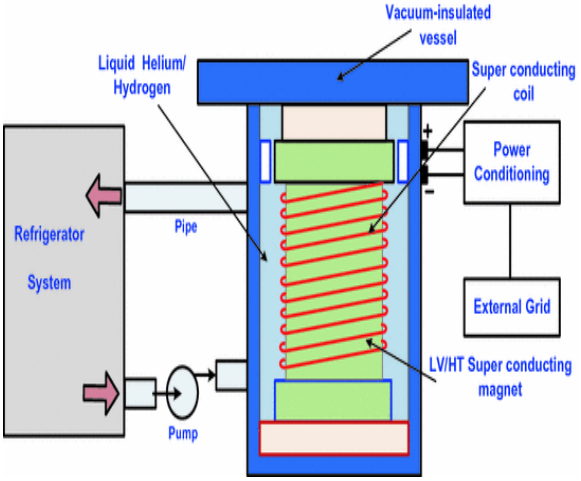

Fig. 1- Block diagram model of SMES

SMES is a huge superconducting coil capable of storing electrical energy in the generated magnetic field, by the current passage through it. The actual power as well as the reactive power can be absorbed or by releasing the SMES coil according to the power requirements of the system. SMES is a long superconducting coil that has the ability to store energy in the form of a magnetic field generated by the direct current flowing in it until the indefinite instant.

Superconducting magnetic energy storage (SMES) have plenty of advantages such as high power density, long periodic life, a high speed, that can be used to meet the balance between the grid and the PV(Solar).

II. SYSTEM MODEL AND OPERATION

Here we discuss about the detailed model of the SMES system which is hybrid connected with the solar (PV cell array). Initially the load was fed by solar system. In a Solar (photovoltaic) system, the energy storages equipment must include the feature of high energy storage efficiency and rapid power response, and the energy storage capability is also high enough. Hence the superconducting magnet is chosen as the energy storage device of the PV system. It is coupled with the solar system with the DC bus. The DC chopper is set to regulate the energy pass through the superconducting coil by charging and discharging of the current of the superconducting magnetic energy storage system. With the synchronize control of converter, the power transfer between the SMES and the PV units or the load can be controlled efficiently.

Based on the operation of the SMES system, there are three means of operation, i.e.,

A. *Charging Mode,*

B. *Freewheeling Mode,*

C. *Discharging Mode*

In all these three modes, SMES unit and PV array were continuously supply the load and also, to regulate the flow of current, there is power conditioning unit which regulates the power flow as per the requirement of the load. At the same instant, Superconducting coil stores energy in the form of DC current and release it according to the load variation.

This whole functioning of the system not only provides the smooth operation, but also increases the

life of the equipment's which further results in low operation and maintenance cost.

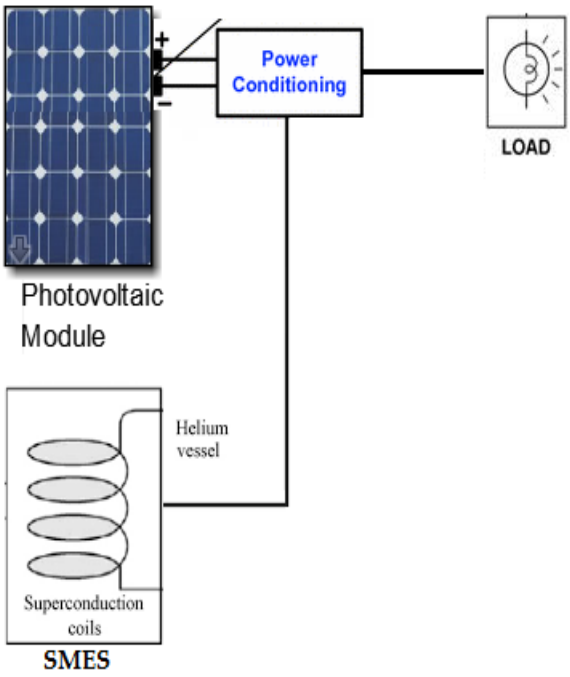

Fig. 2- System model of SMES with PV cell

III. SYSTEM CONTROL TOPOLOGY

According to topology configuration, there are three kinds of power conditioning systems(PCSs) for SMES, namely-

A. Thyristor-based PCS,

The thyristor-based SMES can control mainly the active power, and has a little ability to control the reactive power, also the controls of active and reactive powers are not independent . Here, Charge and discharge are easily controlled by simply changing the delay angle that controls the sequential firing of the thyristors.

B. Voltage source converter (VSC)-based PCS

It includes of a star-delta transformer, a basic six-pulse PWM converter with insulated gate bipolar transistor (IGBT) as the switching device, a two quadrant bidirectional dc-dc chopper using IGBT with a superconducting coil. A voltage bidirectional dc-dc chopper is used to regulate the charge-discharge of the superconducting coil.

C. Current source converter (CSC)-based PCS

The ac side of CSC is interfaced to the supply power lines but dc side is directly connected with the superconducting coil. Practically the SMES system is an inherent current controlled system, which leads to very spontaneous exchange of both real and reactive powers among the CSC and supply grid.

IV. APPLICATIONS OF SMES FOR INCREASING POWER SYSTEM STABILITY

Power system stability is the capability of the system to keep a steady equilibrium state under standard operating conditions and the ability to improve an satisfactory balanced situation when huge disturbances take place. SMES can improve FACTS performance by providing active power in addition to reactive power through the DC bus, finally which results into power system stability. SMES is a capable device for balancing variable active and reactive power from a range of loads.

The source can be controlled to only supply the constant load power. The SMES will be restricted to offer the fluctuating components of the load. Without this power compensating system, voltage fluctuations will be present in the source voltage. Additionally, with this system, the variable component of the source side can be also be compensated by releasing or absorbing energy of the SMES.

Also Load leveling can also be possible by storing energy during off-peak periods and then returning energy on peak by using SMES with the PV array.

The most significant characteristic of the developed solar connected-SMES system is its capability to totally supply any load associated to it during a short system disturbance such as a voltage sag caused by any fault conditions, a transitory interruption caused by lighting , or any supply discontinuity during a load transfer between two available power sources.

V. SIMULATION AND RESULTS

Simulation of SMES system is done in MATLAB. Here, the solar PV system is used as source and result is analyzed. Figure shown below is the simulation model result of proposed Solar based SMES system.

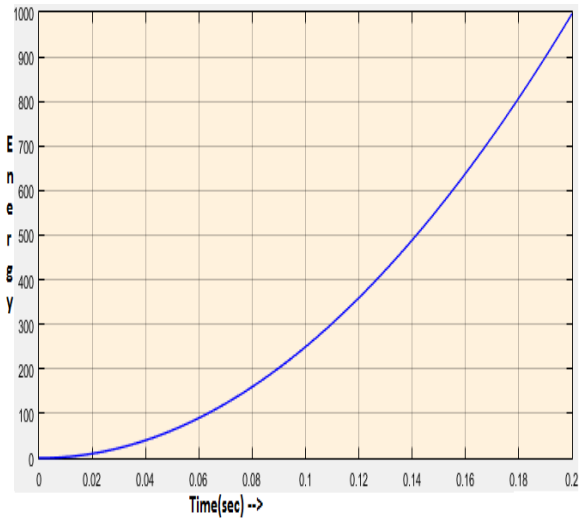

Fig. 3.- Simulation result for Charging state of SMES coil

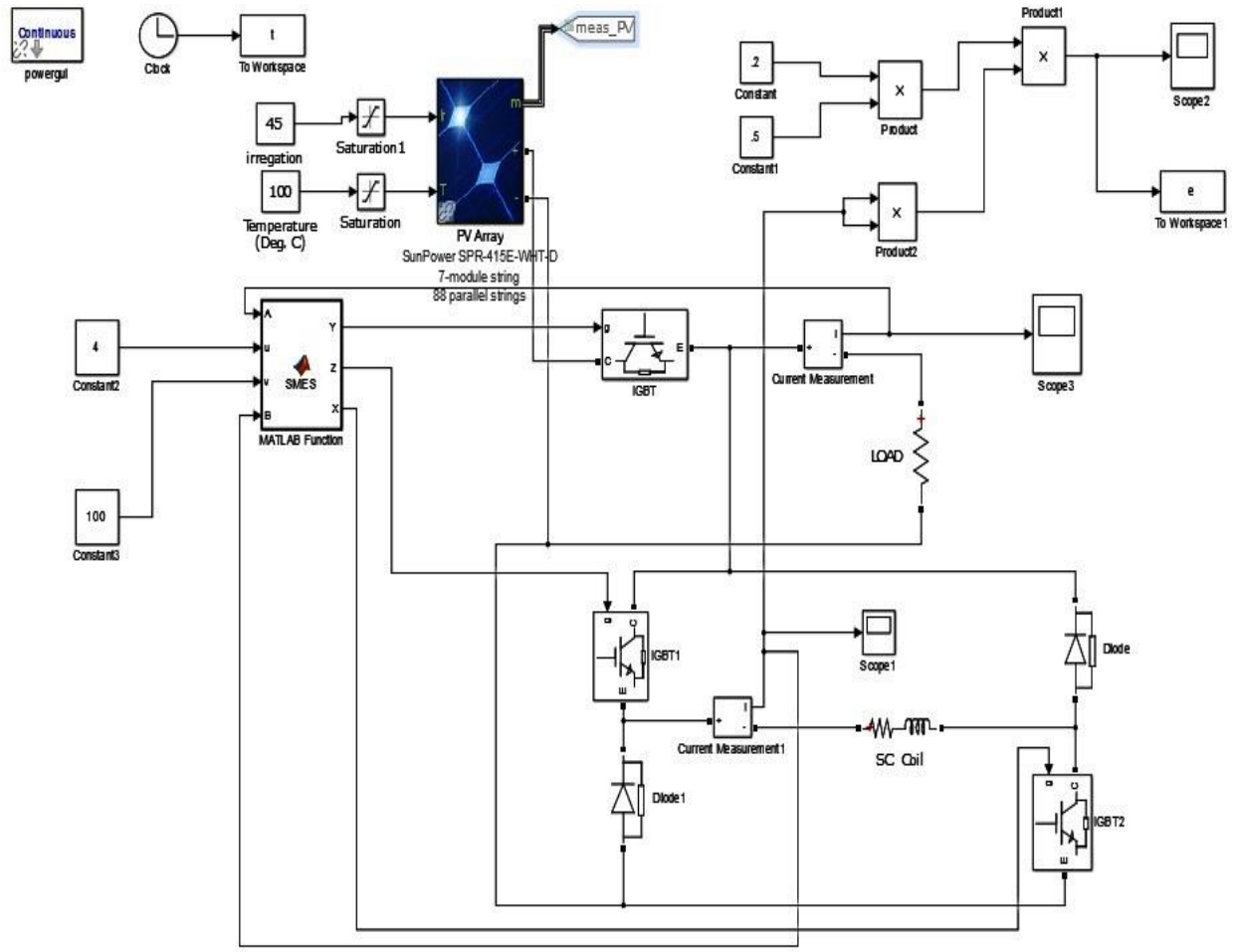

Fig.4- Solar based SMES system

Here, switching of the IGBT is done according to the MATLAB function which works as per the load condition. The result of above shown model is given below.

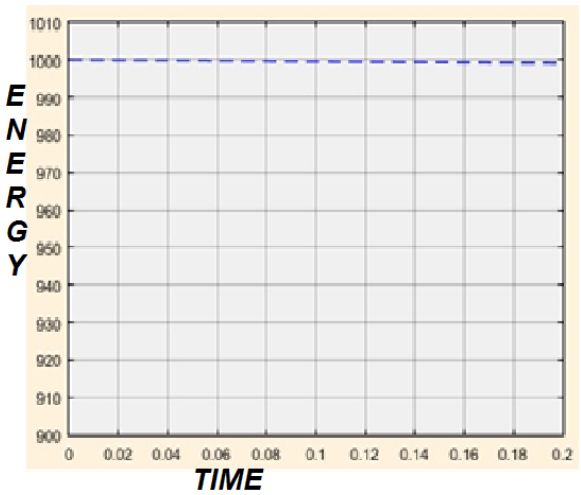

Fig. 5.- Simulation result for holding state of SMES coil

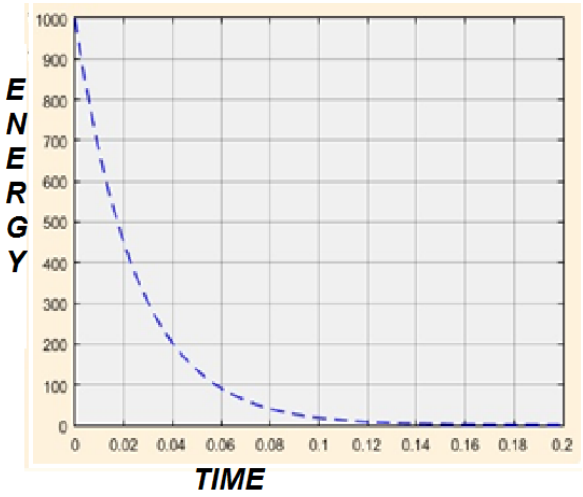

Fig. 6.- Simulation result for discharging state of SMES coil

Using a SMES in solar system can also improve its utility because it gives enhanced result with solar system as compared to any other DC source. Hence, SMES system used with solar system has more advantages as compared to other DC power source.

Now, graph shown in figure 3 represents the charging state of the SMES system. Energy is stored in the SMES during this phase. Just after the energy stored at its full capacity, SMES will stop storing more energy but available with the overall system to compensate the energy required during abnormal load condition. This is shown in the figure 5, where energy stored in SMES is maintained at constant value. During any fault condition, SMES starts releasing energy to the load, which is shown in the figure 6. Therefore, the SMES will provide reliability to the system in addition with it improve the stability with the renewable source and also maintain the proper balance with the conventional energy source and non-conventional energy sources.

VI. ADVANTAGE OF SMES USED WITH SOLAR SYSTEM

There are several advantages of SMES system used in hybrid of solar (PV) system.

- It can provide best solution for storing energy as a back-up where solar is the only source of energy.
- It makes whole power system more reliable and efficient.
- It is environment friendly with low maintenance cost.

VII. CONCLUSION

Comparing to other storage technologies, the SMES has considerable advantages in being capable to speedily inject power into the power system. Also SMES has advantages of high energy density, high charge-discharge rate and no environmental pollution, so it's one of ultimate energy storage equipment.

This research explains that SMES system can be a good for power system stability. SMES with its facility to discharge a huge amount of energy during small periods of time can control the speed of this power to become stable the dc link voltage, which results to enhance the stability and enhance the overall performance of power systems. SMES with PV array can not only improve the stability in the overall system, but also make it more reliable at the same time.

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