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Overview and Detailed Study of SMES System for Energy Storage & Stability Improvement in power System

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Abstract- *Energy storage systems are the recommend potential solutions for enhancing efficiency and power quality. It can also escalate the reliability of power grid with significant penetrations of renewable energy. This paper explains the significant developments and research works under progress in the field of energy storage. This device has improved response time and is appropriate for applications with rapid charge and discharge requirements. For 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 other sources able to absorb and store power and 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 and its significance with system which is based on renewable source with improved reliability.*

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

1. INTRODUCTION

Electrical energy is one of the most significant source 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 years, storage technologies for energy storage have enhanced and delivered significant economic as well as 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 [8][9]. 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.

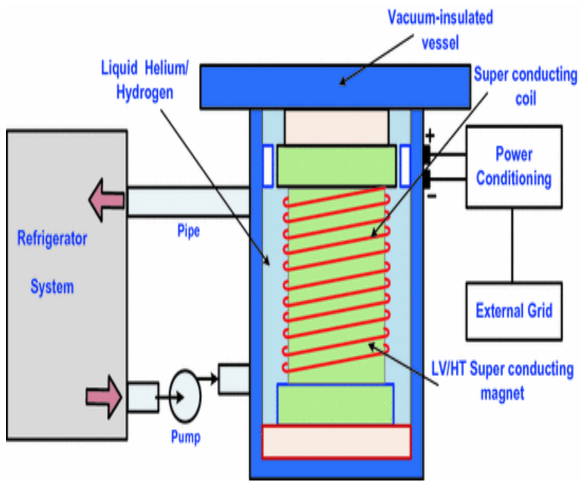

Fig. 1- Block diagram model of SMES

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.

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 along with the reactive power can be absorbed or released by the SMES coil according to the power requirements of the system. SMES is extensive super-conducting coil having ability to store energy in the form of a magnetic field produced by the direct current flowing in it until the indefinite instant.

2. SYSTEM MODEL AND OPERATION

One of the novel storage technologies in the practical research segment is the SMES. This is the system that stores electric energy in the form of a magnetic field in SC coil. The superconducting coil stores the energy by the flow of a direct current based on equation given below. [3][5]

$$E = \frac{1}{2} L I^2 \tag{1}$$

Where, L is the inductance if the SC coil where inductance depends on the size and geometry of the coil and as well as the cross-sectional area of the wire. Inductance of the coil also depends on the material used [2] [5]. A representative SMES system assembly is shown in Fig. 2. [4] As we can see, the system comprises of a superconducting coil, refrigerator and a power conditioning system.

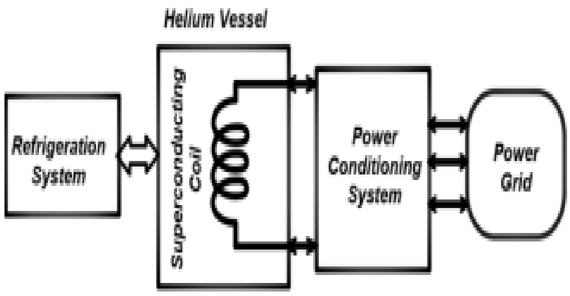

Fig -2: SMES using SC coil

The superconducting material utilized in a SMES system enhances the storage capacity since currents pass with almost nonresistance. However, in order to maintain the coil in the superconducting state it needs to be cryogenically cooled at every low temperature. [2][7]

While integrating with DC source such as battery, a prototype system was developed which demonstrates method of interfacing SMES and battery energy storage systems for a 3- phase load.[1] The system has been shown to autonomously priorities the use of the short-term energy storage system to support the load during deep, short-term voltage sags and a battery for lower depth, long-term under-voltages. This can have benefits inters of improved voltage support capability and reduced costs compared with a SMES-based system.[1][2] us having disadvantages of reduced battery life.

After reviewing both sources such as AC & DC use of SMES, there is single operating principle. Basic principle of operation of the SMES system consist of three means of operation, i.e.,

i) Charging Mode,

ii) Freewheeling Mode,

iii) Discharging Mode

Initially the load was supplied by Battery or other source. In this power 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. [3] 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. [3][4]

In all these three modes, SMES unit continuously monitor the load and supply, to regulate the flow of current, there is power conditioning unit which regulates the power flow as per the requirement of the load.

3. SYSTEM CONTROL TOPOLOGY

Conferring to various topology arrangements, there are mainly three types of power conditioning systems (PCSs) for SMES, namely-

1.1 Thyristor-based PCS,

In the PCS, based on thyristor-controlled SMES mainly controls the active power, and has a slight ability to control the reactive power, in which the controls of active and reactive powers are not independent. Here, Charging and discharging are effortlessly regulated by just changing the delay angle that controls the progressive firing of the thyristors.[3][4]

1.2 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 element, a two quadrant bi-directional dc to dc chopper using IGBT with a superconducting coil. A bidirectional dc-dc voltage chopper is used to regulate the charging & discharging of the SC coil.[1]

1.3 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.

4. 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 also improve the FACTS devices performance by providing an active power in addition to the reactive power through the DC bus bar, finally which results into power system stability. SMES is a capable device for balancing variable active and reactive power from a range of loads. [6]

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. [6][10]

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. [8][10] 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.[6][10].

5. EVOLVEMENT OF NEW IDEA FROM PREVIOUS STUDY &RESEARCH PAPER

This study has several limitations which has to be improved. Current research was based on the AC system and integration with battery. But battery has major drawbacks and has its own limitations in terms of life span and cost. All above mentioned paper are studied thoroughly and major points are considered to suggest this research work with great future scope. 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).Integration with the PV array or the solar system is best suitable application and new research which not only supports the system stability with renewable energy sources but also ensure the reliability.

6. 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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