Power Oscillation Damping and Voltage Stability Improvement using SSSC Integrated with SMES

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ABSTRACT

The power system network is becoming more complex nowadays so maintaining the stability of the power system is very difficult. So we have designed a 12-pulse based Static Synchronous Series Compensator (SSSC) which is operated with and without integration of Superconducting Magnetic Energy Storage (SMES) for enhancing the voltage stability and power oscillation damping in multi area system. Control scheme for the chopper circuit of SMES coil is designed. The model of power system is designed in MATLAB / SIMULINK environment and tested for various conditions. Model is tested SSSC with and without SMES is analyzed for various transient disturbances.

Keywords

Static Synchronous Series Compensator (SSSC), Superconducting Magnetic Energy Device (SMES)

1. INTRODUCTION

Today's modern interconnected power system is highly complex in nature. In this, one of the most important requirements during the operation of the electric power system is the reliability and security. Maintaining stability of such an interconnected multi area power system has become a cumbersome task. As a counter measure against these problems, the Flexible AC Transmission System (FACTS) devices were proposed. Nowadays, the new Energy Storage System (ESS) is interface with FACTS device to increase its performance. In bulk power transmission systems, power electronics based controllers called FACTS, used to simultaneous control of real and reactive power flow control, has been proposed in the literature.

Presently, FACTS devices are a viable alternative as they allow controlling voltages and current of appropriate magnitude for electric power system at an increasingly lower cost .However, a comparable field of knowledge on FACTS/ESS control is quite limited. Therefore, in this work a methodology is proposed to control the power flow, which uses FACTS controllers with energy storage. Using switching power converter-based FACTS controllers can carry this out. Among the different modeling of FACTS devices, SSSC is proposed as the most adequate for the present application well discussed. The DC inner bus of the SSSC allows incorporating a substantial amount of energy storage in order to enlarge the degrees of freedom of the SSSC device and also to exchange active and reactive power with utility grid. Based on a previous study of all energy storage technologies currently available, the use of SMES is proposed for the considered application has been presented. Novelreactive power controllers for STATCOM and SSSC have been reported.

This paper proposes a model of SSSC with and without SMES to carry out the power flow control in the electric system. The SMES coil has been connected to the Voltage Source Converter (VSC) through the dc-dc chopper. Detail on operation, control strategy of SSSC, chopper control of SMES and simulation results for SSSC with and without SMES are presented in the subsequent section.

2. SSSC

A SSSC is build with Thyristors with turn-off capability like GTO or today IGCT or with more and more IGBTs. The static line between the current limitations has a certain steepness determining the control characteristic for the voltage.

The advantage of a STATCOM is that the reactive power provision is independent from the actual voltage on the connection point. This can be seen in the diagram for the maximum currents being independent of the voltage in comparison to the SVC. This means, that even during most severe contingencies, the STATCOM keeps its full capability. Basic STATCOM structure and voltage and current characteristic are shown in fig. 1.

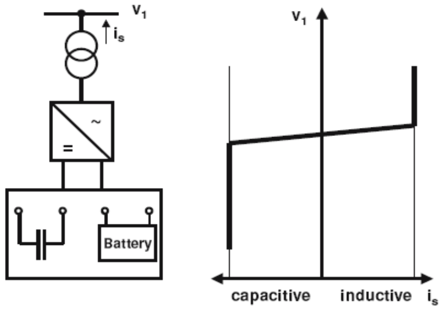


Fig 1: STATCOM structure and voltage / current characteristic

The three phases STATCOM makes use of the fact that on a three phase, fundamental frequency, steady state basis, and the instantaneous power entering a purely reactive device must be zero. The reactive power in each phase is supplied by circulating the instantaneous real power between the phases. This is achieved by firing the GTO/diode switches in a manner that maintains the phase difference between the ac bus voltage ES and the STATCOM generated voltage VS. Ideally it is possible to construct a device based on circulating instantaneous power which has no energy storage device (i.e. no dc capacitor).

2.1 Control Scheme for SSSC

The 6 Pulse STATCOM using fundamental switching will of course produce the 6 N+or-1 harmonics. A 6 Pulse STATCOM is shown in fig.2. There are a variety of methods to decrease the harmonics. These methods include the basic 12 pulse configuration with parallel star / delta transformer connections, a complete elimination of 5th and 7th harmonic current using series connection of star/star and star/delta transformers and a quasi 12 pulse method with a single star-star transformer, and two secondary windings, using control of firing angle to produce a 30(deg) phase shift between the two 6 pulse bridges.

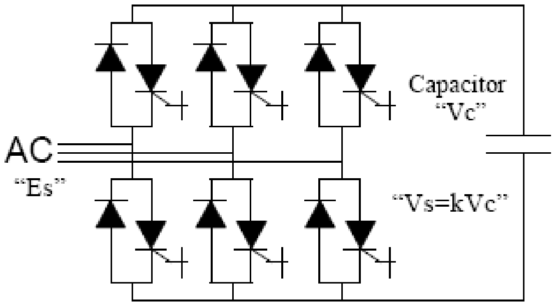


Fig.2 Six Pulse STATCOM

The dc sides of the converters are connected in parallel and share the same dc bus. The GTO valves are switched at fundamental frequency, and the dc voltage varies according to the phase control technique used to control the output voltage.
The SSSC switching is synchronized with respect to the transmission line current iline, and its rms magnitude is controlled by transiently changing the phase shift α between Vdc and Vinj.

The change in the phase shift between the SSSC output voltage and the line current results in the change of the dc capacitor voltage Vdc, which ultimately changes the magnitude of the SSSC output voltage VSSSC and the magnitude of the transmission line current Iline.. The SSSC output voltage VSSSC is controlled by a simple closed loop ; the per unit value of the measured line voltage is compared with the injected voltage and the error of these two values is passed to the PI controller. The output of the PI controller is the angle α, which is added to the synchronizing signal passed to the gate pulse generator by the current synchronization block. To this signal + α, an angle of –pi/2 or +pi/2. added since the SSSC output voltage is lagging or leading the line current by 900 depending on the desired capacitive or inductive operation.

3. SMES

The combination of the two fundamental principles (current with very limited losses; and energy storage in a magnetic field) provides the potential for the highly efficient storage of electrical energy in a superconducting coil. Operationally, SMES is different from other storage technologies in that a continuously circulating current within the superconducting coil produces the stored energy. At several points during the SMES development process, researchers recognized that the rapid discharge potential of SMES, together with the relatively high energy related (coil) costs for bulk storage, made smaller systems more attractive and that significantly reducing the storage time would increase the economic viability of the technology. Thus, there has also been considerable development on SMES for pulsed power systems. A SMES device is made up of a superconducting coil, a power conditioning system, a refrigerator and a vacuum to keep the coil at low temperature, see Figure 4.

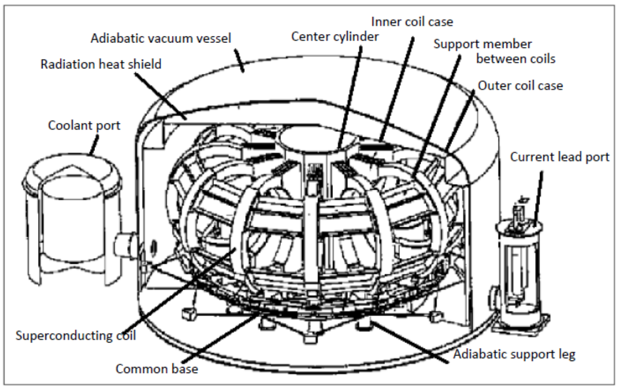


Fig.4 Superconducting Magnetic Energy Storage device

Energy is stored in the magnetic field created by the flow of direct current in the coil wire. In general, when current is passed through a wire, energy is dissipated as heat due to the resistance of the wire. However, if the wire used is made from a superconducting material such as lead, mercury or vanadium, zero resistance occurs, so energy can be stored with practically no losses.

Due to its rapid discharge capabilities the technology has been implemented on electric power systems for pulsed power and system stability applications. The discharge capabilities of SMES compared to several other energy storage technologies is illustrated in Fig. 5.

Fig.5 Illustration of the system power rating and the discharge time of several energy storage technologies. As can be seen, SMES has a relatively low power system rating, but has a high discharge rate.

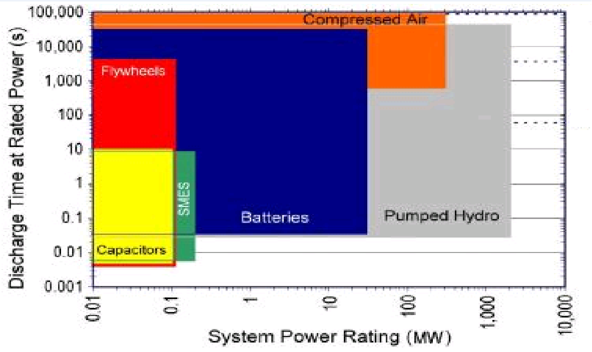


Fig 5: power rating and the discharge time of several energy storage technologies

The overall efficiency of SMES is in the region of 90% to 99%. SMES has very fast discharge times, but only for very short periods of time, usually taking less than one minute for a full discharge. Discharging is possible in milliseconds if it is economical to have a PCS that is capable of supporting this. Storage capacities for SMES can be anything up to 2 MW, although its cycling capability is its main attraction. SMES devices can run for thousands of charge/discharge cycles without any degradation to the magnet, giving it a life of 20+ years.

3.1 Chopper Control for Smes

SMES consists of a coil with many windings of superconducting wire that stores and releases energy with increases or decreases in the current flowing through the wire. Although the SMES device itself is highly efficient and has no moving parts, it must be refrigerated to maintain the superconducting properties of the wire materials, and thus incurs energy and maintenance costs. SMES are used to improve power quality because they provide short bursts of energy (in less than a second). An electronic interface known as chopper is needed between the energy source and the VSC. For VSC the energy source compensates the capacitor charge through the electronic interface and maintains the required capacitor voltage. Two-quadrant n-phase DC-DC converter is adopted as interface. The DC-DC chopper allows to reduce the ratings of the overall power devices by regulating the current flowing from the superconducting coil to the inverter of the SSSC.

4. MODELING AND CONTROL STRATEGY

A power system network is matlab/simulink environment. The designed model is shown in fig. 4.1. As shown in fig. a three phase power system network is designed in which the power is fed by three generators. All the three generators are of same ratings with voltage rating of 500KV and MVA rating of 8500 MVA. 1 load of 300MW and 200MW are connected in the two ends of the lines. A measurement of line voltage, active and reactive power has been taken by using different measuring instruments of MATLAB.

4.1 Matlab Model Using Sssc

The model of power sysyem is designed in SIMULINK and a fault is produced to show various comparison of transiants.A FACT family device SSSC is designed and connected into the network. Model of power system using SSSC is shown in fig. 6. SSSC is connected in series with the transmission line as shown in fig.6. The purpose of SSSC is to inject a voltage with controlled angle in series with line to reduce the power oscillations damping time and short circuit current.

Then the values of voltage, active and reactive power and current are measured of the system for three phase fault by using SSSC.

4.2 MatlabModel Using Sssc Integrated. With Smes

Then the model is designed with connecting SMES in the model in parallel with the capacitor of SSSC. The performance of network is checked by integrating SMES with SSSC. Power system model using SSSC and SMES is shown in fig.7. SMES is simply a storage device conned in parallel with SSSC which is used to increase the magnitude of capacitor voltage. Then the values of voltage, active and reactive power and current are measured of the system for three phase fault by using SSSC and SMES. The result values of both the circuits are compared.

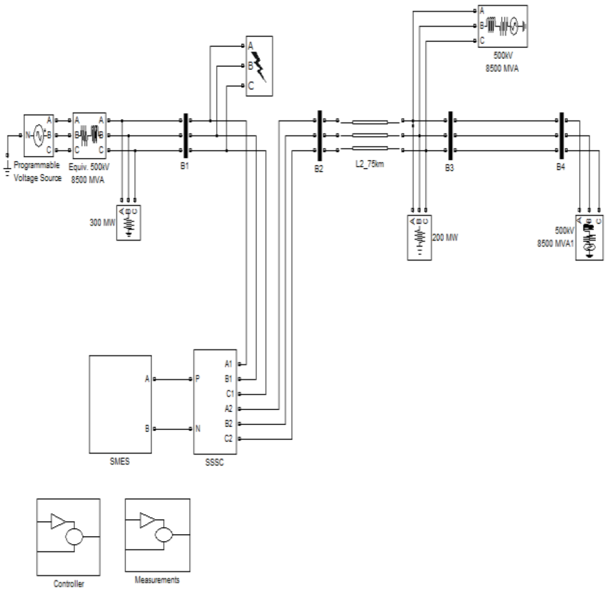


Fig.6 Simulink model with SSSC

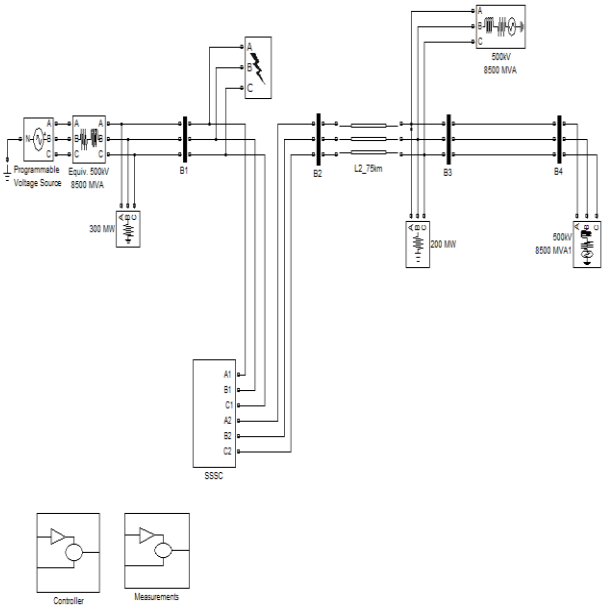
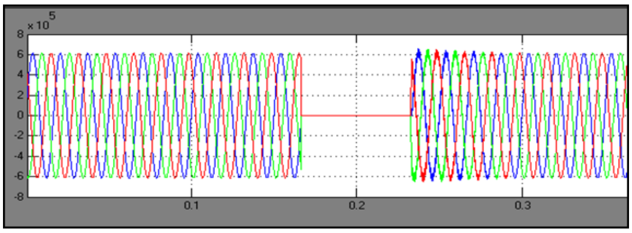


Fig.7 Simulink model with SSSC and SME

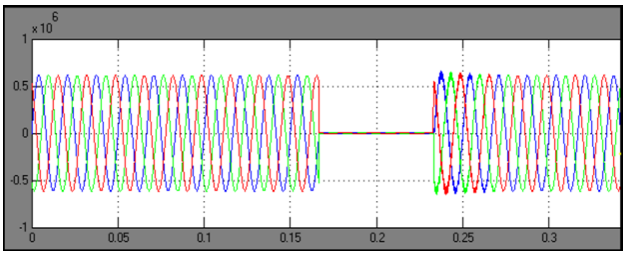
5. RESULT AND DISCUSSIONS

The simulation network is tested for three cases which are, Case (a) Without Using SSSC and SMES, Case (b) With SSSC and without SMES, and Case (c): With SSSC and with SMES. Then the results of all cases are compared.

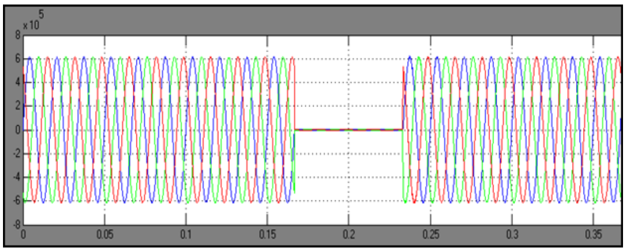
Simulation results of various cases are shown below:



Case (a)

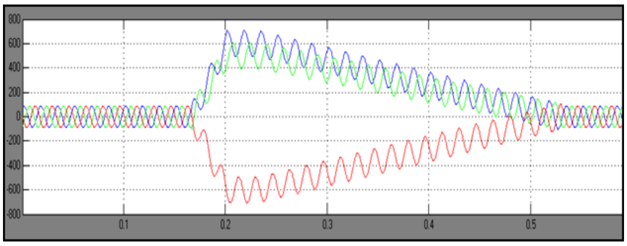


Case (b)

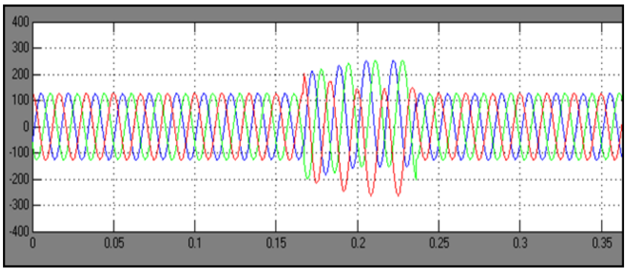


Case (c)

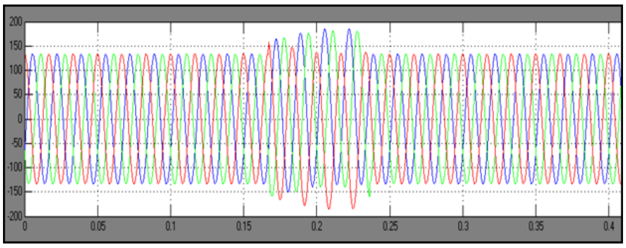
Fig.8 Waveform of network voltage



Case (a)

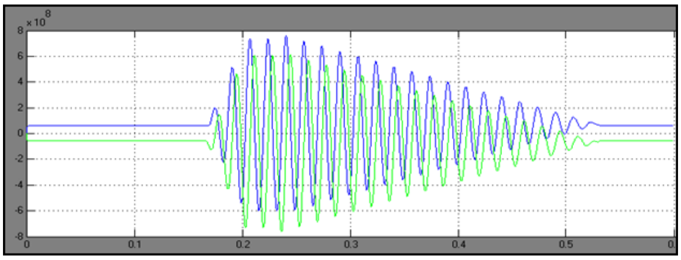


Case (b)

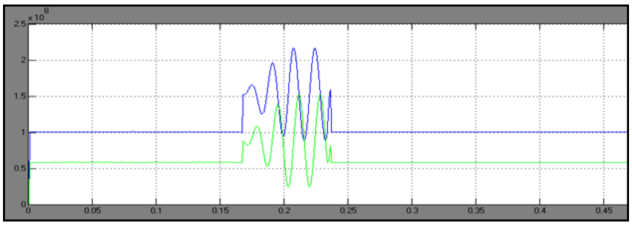


Case (c)

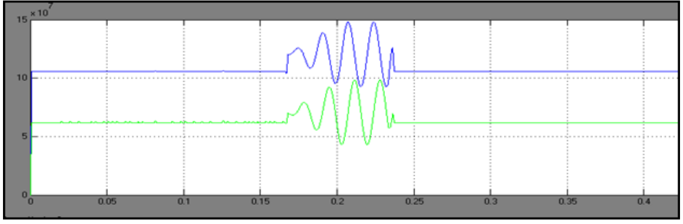
Fig.9 Waveform of network current



Case (a)



Case (b)



Case (c)

Fig.10 Waveform of power

The fault occurrence time is 0.1667 seconds and clearance of fault is 0.2333 seconds. In fig. 8 voltages of all the cases are compared. In fig. 9 current of all case are compared and settling time of current of case (a) is 0.3433seconds which is very large as compared to case (b) and case (c) which is 0.2370 seconds and 0.2358 seconds respectively. In fig.10 waveform of active and reactive power of all cases are compared and it is seen that power oscillations of case (b) and (c) are oscillated in less time as compare to case (a). Power oscillation clearing time for case (a) is 0.3633 seconds, case (b) is 0.2380 seconds and case(c) is 0.2315 seconds.

6. CONCLUSION

The dynamic performance of the SSSC with and without SMES for the test system is analyzed with Matlab/simulink. In this paper SMES with chopper control plays an important role in real power exchange. SSSC with and without SMES has been developed to improve transient stability performance of the power system. It is inferred from the results that the SSSC with SMES is very efficient in transient stability enhancement and effective in damping power oscillations and to maintain power flow through transmission lines after the disturbances.

7. REFERENCES

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