International Journal of Science and Modern Engineering (IJISME)
ISSN: 2319-6386, Volume-1 Issue-6, May 2013

A Novel Approach to Interarea Oscillation Damping by using Statcom-Smes System

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Abstract*—*Interarea oscillations create problems like damage of generators, increase line losses, and increase wear and tear on network components.STATCOM is capable of damping such oscillation and it reduces all the above mentioned problems due to interarea oscillations. In this paper a new controlling technique that uses combination of STATCOM-SMES system is discussed to damp inter area oscillations in an effective manner

Index Terms*—*Static Synchronous compensator (STATCOM), Super Conducting Magnetic Energy Storage Systems (SMES), Inter Area Oscillations

I. INTRODUCTION

In many power systems electromechanical oscillations are observed world wide[1],[2],[3]. These oscillations can be classified in to two types; they are local mode oscillations and inter area oscillations. Such oscillations are produced due to swinging of synchronizing generators with each other. In this situation rotor of the machine behaves as rigid bodies and oscillating energy will be exchange between the machines through transmission line. Local mode oscillations having frequency ranges from .7 HZ to 2HZ and this phenomena is related with a single generator or generator plant.Inter mode oscillations having frequency ranges from .1 HZ to .8hz and this phenomena is related with a number of generators widely separated geographically[1],[2],[3].Traditionally we use Power system stabilizers on generator excitation control system to damp such electromechanical oscillations. Power system stabilizers are effective but usually they are designed for local modes and in large power systems they will not provide enough damping for interarea modes.Inter area oscillations create problems like damage of generators, increase line losses, and increase wear and tear on network components.Hence in order to improve the damping of these modes FACTS controllers[6,7] like Static synchronous compensator (STATCOM)[4,14],Static series synchronous compensator (SSSC)[11,13],Unified power flow controllers(UPFC)[8,9,10] etc. are used.Static Synchronous Compensator or STATCOM is a shunt-connected device which inject reactive current into the AC system.This leading or lagging current, which can be controlled Independently of the AC system voltage, is supplied through a power electronics-based variable voltage source.

DC capacitor in STATCOM is capable of charging or discharging to compensate for converter losses in the STATCOM. During large transients, the energy stored in the dc capacitor is inadequate to accomplish significant damping without severe dc voltage degradation. For overcoming this drawback we use substantial power supplies. The term substantial [6] means enough to deliver active power to the power system over an interval of a few seconds or more.If we use electro chemical battery [6, 12] as substantial power supply, we have to face the problems like high impedance, high cost, chemical reaction occurs on electrodes, higher ageing, high heating levels etc. If we use super capacitor [1, 6, 12]as substantial power supply we have to face the problems like low energy density, low voltage, higher self-discharge and unable to use full energy spectrum etc. so in this paper introducing a new control technique using STATIC SYNCHRONOUS COMPENSATOR(STATCOM) with superconducting magnetic energy storage system (SMES) [11, 12, 15, 6] in order to damp the interarea oscillation in an effective manner.

Comparing with other substantial energy supplies SMES having the advantages of high energy density, fast response, high efficiency, minimum energy loss during the conversion etc.

II. STATCOM OPERATION

Static Synchronous Compensator or STATCOM is a shunt-connected device which injects reactive current into the AC system. This leading or lagging current, which can be controlled independently of the AC system voltage, is supplied through a power electronics-based variable voltage source. The STATCOM does not employ capacitor or reactor banks to produce reactive power as the Static VAR Compensators (SVC) does. In the STATCOM, the capacitor is used to maintain a constant DC voltage in order to allow the operation of the voltage-source converter.

STATCOM can fulfill function of reactive shunt compensation; Besides STATCOM allows a secondary but important function such as stability control to suppress power system oscillations improving the transient stability of power system. The voltage source inverter is a DC to AC switching power converter using Gate Turn-off (GTO) thyristors in appropriate circuit configurations in order to generate a balanced set of three sinusoidal voltages at the fundamental frequency. From the control point of view, it is important to distinguish between two types of voltage source inverters that can be used. One type is based on a phase control scheme involving multi-connected, elementary inverters in an appropriate multi-pulse configuration.

Manuscript Received on May 2013.

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The other inverter type operates on the basis of Pulse Width Modulation (PWM) switching techniques where active and reactive power supplied by the inverter canbe independently controlled. In practice, for high power utilities applications, phase control is used in a scheme of *k*-pulse inverters. Presently, PWM is regarded uneconomical for transmission applications due to high switching losses and unavailability of fast switching GTOs.An elementary voltage source inverter based on a phase control scheme consists of six self-commuted semiconductor switches, each of which is shunted by a reverse parallel-connected diode. With a DC voltage source, the inverter can generate a balanced set of three quasi-square voltage waveforms at a given frequency. The output voltage waveform of the elementary six pulse inverter contains high harmonics level, making this simple inverter impractical for high power applications. By using the principle of harmonics neutralization , the input and output of *n* basic six-pulse inverters, operated with appropriate relative phase-shifts, can be combined so as to obtain an overall *k*=6 *n* multi-pulse structure.. The four inverters are shunt-connected in the DC side and series-connected inthe AC side through coupling transformers. By combining two 24-pulse VSIs, phase-shifted 7.5degrees from each other, an equivalent 48-pulse inverter can be created, thus avoiding the use of large banks of capacitors for harmonics filtering

The output voltage waveform of the 48-pulse inverter is not a perfect sine wave; it is a staircase approximation of a sine wave. However, the multi-pulse converter supplies an almost sinusoidal current to the AC system, the current being smoothed through the tie-reactance of the coupling transformer. As a result, the net three-phase instantaneous power (VA) at the output terminal of the converter fluctuates slightly, making the 48-pulseinverter satisfactory for high power utility applications.

Diagram of STATCOM with SMES System

Reactive power flow exchanged by the STATCOM at the coupling bus or output N terminal (node 2) for each phase can be expressed through Eqs1

$$Q = -\frac{V_{ac}^{\ 2}}{X} + \frac{V_{ac} \cdot V_{inv}}{X} \cdot \cos\alpha \qquad (1)$$

where: *Vac*is the rms voltage at the output terminal of the STATCOM (node 2); *X*=ω*L*is the coupling transformer equivalent impedance due to the transformer leakage inductance; α is the phase-shift between the voltage generated by the inverter, the rms voltage of which is *Vinv*(node 1), and the output terminal voltage of the STATCOM.

From these equations, it can be concluded that the reactive power exchange between the inverter and the AC system can be controlled fundamentally by varying the amplitude of the three-phase output voltage *Vinv*.

III. STATCOM-SMES INTEGRATED SYSTEM

A functional model of a STATCOM integrated with energy storage is shown in Fig. 2. The basic component of the STATCOM is the voltage-source inverter (VSI)with semiconductors devices having turn-off capabilities (typically GTOs). It is also made up of a coupling step-up transformer, a DC capacitor, an interface device with the energy storage system and the control block of the STATCOM/SMES. This control block produces the switching signals for the VSI thyristors and the interface with the ESS (SMES).

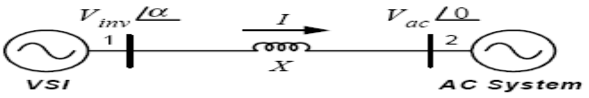

Fig 1: Single Line

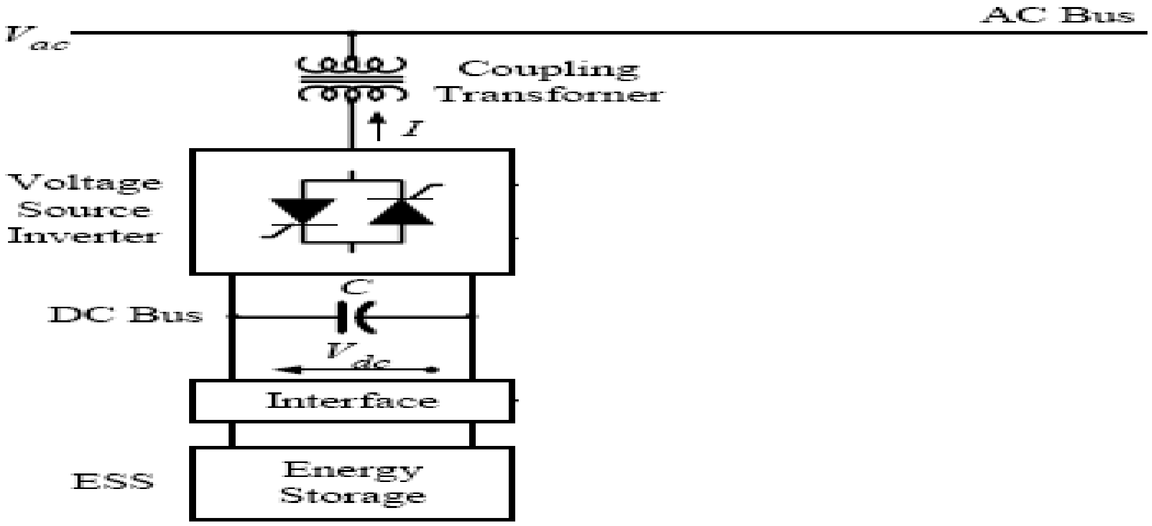

Fig 2: STATCOM with SMES

Super conducting magnetic energy storage system (SMES) can be used as rapid-discharge Energy storage for power applications as shown in the Figure No 2. In steady-state, the DC-link capacitor serves as a DC voltage from which the sinusoidal voltage waveform is constructed through pulse width modulation. The voltage of this capacitor is tightly controlled so that there is no degradation in the Staircase waveform. During small transients, the DC capacitor will charge and discharge to compensate the voltage in the converter losses in the STATCOM. During large transients, however, the ability to exchange active power with the external power system is desirable to aid in damping oscillations. In this situation, the energy stored in the DC capacitor is inadequate to accomplish significant damping without severe DC voltage degradation. By utilizing a bidirectional DC -DC converter, the SMES can be fully discharged without significantly impacting the voltage across the dc capacitor.

For this reason, an SMES is an attractive solution for providing large amounts of short-term active power.

IV SMES CHOPPER CONFIGURATION

An electronic interface known as chopper is neededbetween the energy source and the VSI. For VSI the energy Source compensates the capacitor charge through the electronic interface and maintains the required capacitor voltage. Two-quadrant n-phase DC-DC converter as shown in Fig. 3 is adopted as interface. Here ‘n’ is related to the maximum current driven by the superconducting device. The DC-DC chopper solves the problems of the high power rating requirements imposed by the superconducting coil to the UPFC. 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 UPFC.The two quadrant single-phase chopper is composed of many shunt connected diode-thyristor legs that permit the driving of the high current ratings stored in thesuperconducting coil. The chopper has 3 modes ofoperation to perform the charge, the discharge and thestorage in the SMES device. The chopper is operated in astep down configuration in the charge mode of thesuperconducting coil. Here, the IGBT “s1” isoperated with the duty cycle ‘D’ while the IGBT “s2” is kept on at all times. The relationship between thecoil voltage and the DC bus voltage is given by the equation.

$$V_{SMES} = D * V_{DC} \ (2)$$

Once the charging of the superconducting coil is completed, the operating mode of the DC-DC converter is changed to the stand-by mode for which the IGBT “s1” is kept off all the time while the IGBT “s2” is kept on constantly. In the discharge mode, the chopper is operated in a step up configuration. The set of thyristors “b” is operated with duty cycle D while the set of thyristors “a” is kept off at all times.

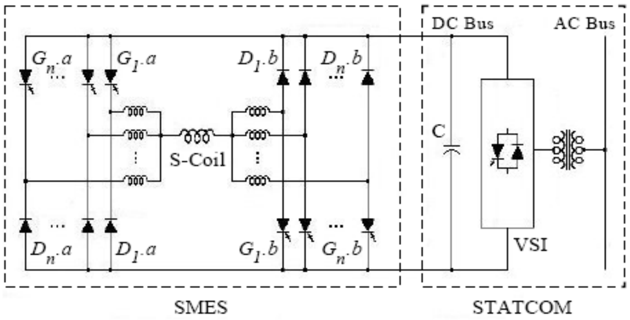

Fig 3: SMES Chopper Configuration

The relationship between the coil voltage and the DC bus voltage is given by the equation

$-V_{SMES} = (1 - D) * V_{DC}(3)$
The duty cycle ranges from 0 to 1. The relationship between the DC bus voltage and the output voltage of the
Inverter is given by the Eq.
$V_{DC} = K_a V_{inv}(4)$
Where,

$K_a = k * a(5)$

k = Pulse number
a = Ratio of the coupling transformer

V. RESULTS AND DISCUSSIONS

In the testing system, a solid symmetrical fault has been applied on bus at 0.0167 s and has been cleared in 0.41 s. The location and duration of the fault were chosen to provide a significant disturbance to the interior of the power system and the below comparisons shows how interarea oscillations are damped and how dc link (capacitor) provides compensation .

A. Reactive Power Comparison with STATCOM & STATCOM with SMES

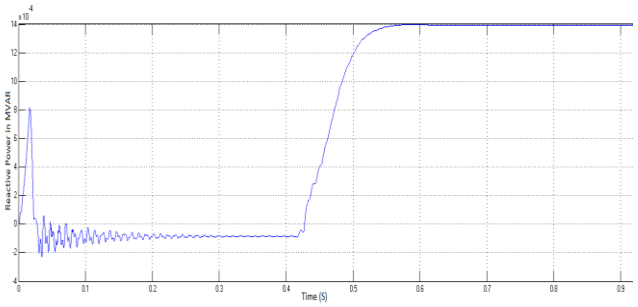

Fig 4: Reactive Power with STATCOM

Figure No 4 and Figure No 5 shows that the simulation result for reactive power (Q) for test system with fault and for damping the oscillations in both cases, STATCOM alone and STATCOM with SMES.A solid symmetrical fault has been applied on bus at 0.0167 s and has been cleared in 0.41 s.

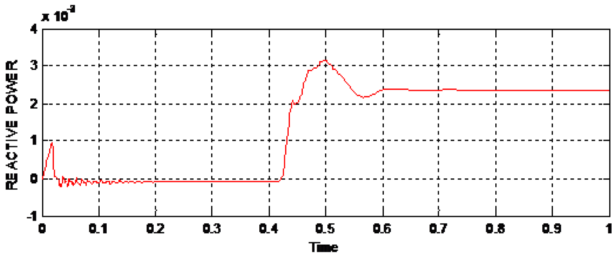

Fig 5: Reactive Power with STATCOM and SMES

It is clear thatBefore the settling of reactive power, power oscillations are high in the case of STATCOM alone compared with the combination of STATCOM and SMES.Also power oscillations are damped quickly when we use the combination of STATCOM and SMES

B. DC Link Voltage Comparison with UPFC & UPFC with SMES

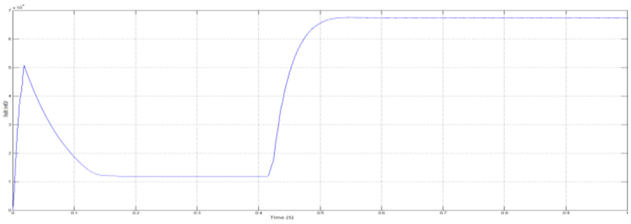

Fig 6: DC Link Voltage with STATCOM

Figure No 6 and Figure No 7show the simulation result for voltage in test system with fault and for both cases. A solid symmetrical fault has been applied on bus at 0.0167 s and has been cleared in 0.41 s.It can be seen that the voltage stability increase in case with combination of STATCOM andSMES when compared with STATCOM alone while providingThe compensation voltage for the faulted system. It is observed that settling time for the combination of STATCOMand SMES is minimum when compared with the STATCOM alonewhile providing the voltage compensation for the faulted system

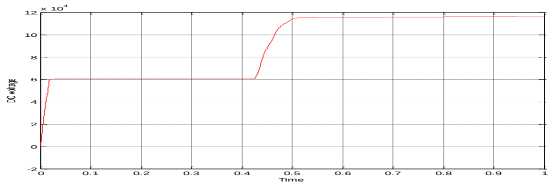

Fig 7: DC Link Voltage with STATCOM and SMES

V. CONCLUSION

In This paperthe importance and technical significance of SMES with STATCOM is elaborated . Advantages of using SMES in connection to STATCOM in the power system for minimizing the interarea oscillations of the power system and Detailed MATLAB/SIMULINK modeling and control of the integration of a STATCOM with a SMES, and its dynamic response to interareaoscillationscaused by a 3-phase fault is discussed. The simulation result shows that combination of STATCOM-SMES system provide better inter area oscilation dampingthan a STATCOM alone system

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