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Improving the Performance of an Ac/Dc Power System by Using the Application of CSC Based SMES Unit

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ABSTRACT:

This paper mainly focuses on to improve the performance of the power system in case of ac and dc by using super conducting magnetic energy system (SMES). To investigations has been performed by the inter connection of high voltage direct current (HVDC) system connected to turbine generator. The impact of hvdc station during faults on impact of twisting the torques induced in turbine generator circuit. In order to reduce the harmonics on ac and dc side during faults, misfire, short circuit faults and also controls the current by using with SMES and without SMES and simulation results are performed based on time response as well as harmonics. The performance is better for SMES when compared with without SMES and the simulation results are shown in the MATLAB SIMULINK model.

INDEX TERMS:

High voltage direct current (HVDC), super conducting magnet energy storage (SMES), misfire.

1.INTRODUCTION:

HVDC is a feasible alternative for transmission of power through longer distances. In transmission system HVDC is a feasible alternative to improve the reliability purposes. Some problems occurred in case of interconnection systems mainly in HVDC system and the generator turbine set such as faults, misfire, short circuit faults, and flashover. The impact n HVDC system during faults is to increase the harmonics, instability, over losses, generator problems, efficiency is also decreases. The problems mainly occurring on inverter side .So, in order to reduce the problems in ac and dc side SMES is used. It cannot focus on dc line fault because it is more danger than ac three phase to ground fault. He mainly focuses the impact on HVDC system on transient disturbances such as misfire, faults, flash over and short circuit faults occurred in inverter side during steady state torque reached to generator turbine. The main concept inside the project is to use of SMES and without use of SMES in order to achieve the current stresses in inverter side on generator turbine connected to HVDC system during transient disturbances such as misfire, short circuit faults, flash over and to improve the better simulation results are performed by using EMTDC/PSCAB Program.

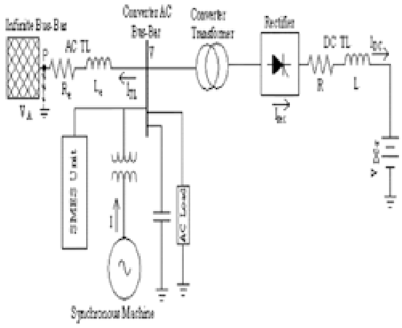

Fig.1 single line diagram of the system

II. SYSTEM UNDER STUDY:

Fig.1 represents the single line diagram under study. It consists of 6-pulse dc or ac converter station connected to a synchronous machine terminal. Under investigating, assume a short transmission line is to be connected to the converter station to an infinite bus bar. As the load is purely resistive is connected to the converter station of the ac bus bar system. Reactive power is supplied by the capacitors which is connected to the converter side of AC bus bar in order to support the system and also mitigate the harmonics for higher order of the line current in case of ac side. The use of SMES at the synchronous machine terminals to provide satisfactory damping for generator turbine set. Several investigations has been taken to interaction between twisting the oscillations in the shaft system and electrical system to generate the non-linear waveform and developed in order to limit the current and voltage using superconducting inductor.

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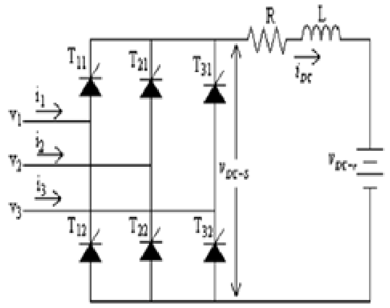

Fig.2 Bridge rectifier

A. Synchronous machine:

To recognize the phase voltage and current must be engaged to express the minutiae of the consecutive commutation developments of the converter and it is associated through a step up transformer to an infinite bus bar and ac transmission line.

B. Mechanical system:

The turbine generator organisation is exhibited as a linear multimass spring dashpot system. Every rotating element is demonstrated as a damped mass and each shaft is displayed as a spinning massless spring with its spring stiffness constant.

III. SMES Operation unit:

Fig. 3 represents the block diagram of SMES unit. The unit consists of inductor present in the super conducting is also known as heart of the unit. It consists of 6-pulse with 2-series pulse dc or ac inverter connected to 3-phase system through star-star or delta-star step down transformer and the voltage is applied to 6-pulse and it will generate 12-pulse generated with a phase angle 30 degrees in order to utilise to cancel the 5th and 7th order harmonics in ac side and 6th order harmonics in dc side is to be filtered.

The voltage passing across the terminal can be varied with changing the phase anglesα_1, α_2in order to generate the negative and positive values and current passing through the inductor present in the super conductor is unidirectional.

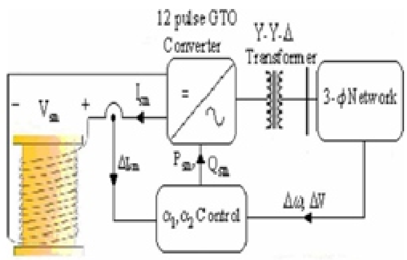

Fig. 3 smes unit

If you can hand-picked for phase angles is equivalent, numerous difficulties will arise which becomes effective. In order to diminish the consequence we can enhance PID controller is used in other cases. In other case phase angles are not equivalent the problems are not finding in order to eradicate the equal phase angle case

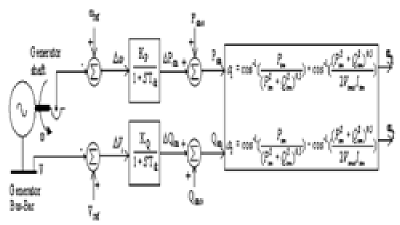

Fig.4 Smes controlling for proposed system

IV. UNIT CONTROLLING OF SMES:

The voltage based on converter theory on dc side is expressed as

$$V_{sm} = V_{smo}(\cos\alpha_1 + \cos\alpha_2) \qquad (1)$$

The current and voltage across the inductor present in the super conductor is

$$I_{sm} = \frac{1}{L_{sm}}\int_{t_o}^{t} V_{sm}\,d\tau + I_{smo} \qquad (2)$$

Inductor is to be charged at maximum rate and to obtain the positive voltage Vsm.The current present in the inductor is increases with increase in energy present in the magnetic field energy and the energy stored in the inductor. When the current present in the inductor reaches final value and the current is controlled and the voltage is zero across the inductor. The amount of energy is stored in case of magnetic field is expressed as

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$$W_{sm} = \int \frac{B^2}{2\mu} dV \quad (3)$$
$$= \frac{1}{2} L_{sm} I_{sm}^2 \quad (4)$$

The SMES unit is absorbed or delivered by the active and reactive power and is expressed as

$$P_{sm} = V_{smo} I_{sm} (\cos\alpha_1 + \cos\alpha_2) \quad (5)$$
$$Q_{sm} = V_{smo} I_{sm} (\sin\alpha_1 + \sin\alpha_2). \quad (6)$$

SMES can operate 3 modes of operation.

1) The standby mode when firing angles are equal to 90, the voltage across the SMES coil is equal to zero, and the SMES coil current is at its rated value; consequently, there will be no energy transferred between the SMES unit and the ac system.

2) Charging mode at firing angles of less than 90, where power will be transferred from the ac system to the SMES unit. 3) Discharging mode at firing angles greater than 90, where power will be injected from the SMES unit into the ac system. Adjusting the values of the firing angles can control the rates of charging and discharging. Using (5) and (6), the firing angles of the converter under four-quadrant operation can be calculated as [10], [8].

$$\alpha_1 = \cos^{-1}\left(\frac{P_{sm}}{\sqrt{P_{sm}^2 + Q_{sm}^2}}\right) + \cos^{-1}\left(\frac{\sqrt{P_{sm}^2 + Q_{sm}^2}}{2V_{smo} I_{sm}}\right) \quad (7)$$

$$\alpha_2 = \cos^{-1}\left(\frac{P_{sm}}{\sqrt{P_{sm}^2 + Q_{sm}^2}}\right) - \cos^{-1}\left(\frac{\sqrt{P_{sm}^2 + Q_{sm}^2}}{2V_{smo} I_{sm}}\right). \quad (8)$$

In order to use the SMES unit as a tensional mode stabilizer, the active power transferred between SMES and the ac system is controlled continuously depending on the measured speed deviation of the turbine-generator rotor. The reactive power control is usually for the purpose of voltage stabilization. Then the reactive power transferred between SMES and the ac system is controlled continuously depending on the measured voltage deviation of the generator terminal bus.

V. DETERMINATION OF SMES CONTROL LOOP GAINS:

The stability of a machine depends on the existence of two torque components: a synchronizing torque that is in phase with the power (torque) angle perturbations and a damping torque that is in phase with the speed deviations. Thus, the change in electrical torque of a synchronous machine following a perturbation can be represented by [8].

$$\Delta T_e = T_S \Delta\delta + T_D \Delta\omega. \quad (9)$$

For a machine to remain synchronized after the perturbation, both torque components and have to be positive and sufficiently large. Lack of sufficient damping leads to oscillatory behavior of machine output quantities and sometimes even to instability. The torque components and can be improved by selecting proper values for the SMES control loop gains and. Fig. 6 shows the electromechanical Eigen values mode for various values of and when the SMES was located at the generator terminal. In Fig. 6, the effectiveness of the simultaneous control of active and reactive power can be compared with the reactive power control corresponding to and with the active power control. The key problem to improve the dynamic performance of power systems using SMES is to reduce the influence of the cross coupling between -modulation and -modulation. The SMES unit must be able to regulate active and reactive powers of the power system by firing angle control of the converters.The linearized equations of P_SM and Q_SM as given in (5) and (6) can be written in matrix form as:

$$\begin{bmatrix} \Delta P_{sm} \\ \Delta Q_{sm} \end{bmatrix} = \begin{bmatrix} -V_{sm0} I_{sm0} \sin\alpha_{10} & -V_{sm0} I_{sm0} \sin\alpha_{20} \\ V_{sm0} I_{sm0} \cos\alpha_{10} & V_{sm0} I_{sm0} \cos\alpha_{20} \end{bmatrix} \times \begin{bmatrix} \Delta\alpha_1 \\ \Delta\alpha_2 \end{bmatrix} + \begin{bmatrix} V_{sm0}(\cos\alpha_{10} + \cos\alpha_{20}) \\ V_{sm0}(\sin\alpha_{10} + \sin\alpha_{20}) \end{bmatrix} \Delta I_{sm}. \quad (10)$$

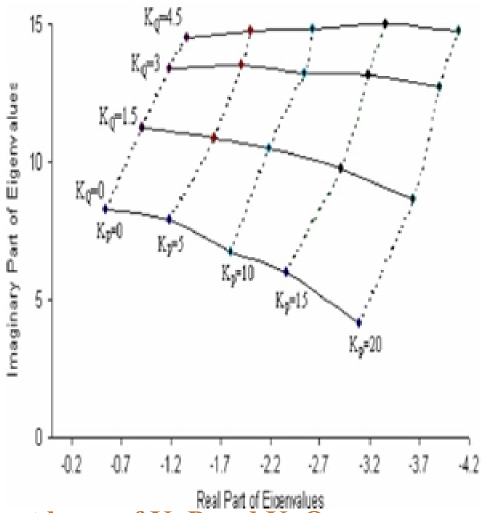

Fig.5 root locus of K_P and K_Q

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It should be noticed that is almost constant. Thus, the deviations of and are influenced mainly by the deviations. Equation (10) represents a coupled control system. The coupling coefficients are the off diagonal elements. In order to realize the perfect decoupling, these elements should be eliminated. Then for this control algorithm, the decoupling condition Is:

$$\sin \alpha_{20} = \cos \alpha_{10} = 0. \qquad (11)$$

Equation (11) implies that perfect decoupling control can be easily realized by adjusting the initial firing angles and to be 90 and 0, respectively. Under this condition and neglectingThe SMES coil current deviation, the decoupled outputs are

$$\Delta P_{\rm sm} = -V_{\rm sm0} I_{\rm sm0} \Delta\alpha_1 \qquad (12)$$

$$\Delta Q_{\rm sm} = V_{\rm sm0} I_{\rm sm0} \Delta\alpha_2. \qquad (13)$$

The linearized equation of the voltage across the superconducting inductor as given in (1) is

$$\Delta V_{\rm sm} = -V_{\rm sm0} \sin(\alpha_{10}) \Delta\alpha_1 - V_{\rm sm0} \sin(\alpha_{20}) \Delta\alpha_2. \qquad (14)$$

At normal operating conditions, both and are zeros. Thus is also zero, and there will be no power transfer between the SMES unit and the power system. It should be noticed that for any values of the firing angles, the following equation is satisfied:

$$\sqrt{P_{\rm SM}^2 + Q_{\rm SM}^2} = S_{\rm SM} = \text{Constant}. \qquad (15)$$

Thus, by controlling the converter firing angles and, both SMES active power and reactive power can be controlled smoothly and independently in circular range of operation.

VI. ANALYTICAL RESULTS:

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All the nonlinear differential equations describing the system under study shown in Fig. 1 can be linearized at the initial operation point to obtain the linear differential equations. To investigate the effect of the SMES unit in improving transient stability and suppressing torsion oscillations in power systems, the control system has been analyzed by calculating the eigenvalue of the linearized differential equations representing the dynamics of the whole system.

Table I shows the torsion modes eigenvalue of the studied system under different operating conditions without and with the SMES unit.It can be seen that the open loop system (no SMES) at Po=1.2 p.u. is unstable as the second torsion mode is located in the right side of the s-plane. Furthermore, the damping of the low-frequency oscillation which is dominantly affected by the electromechanical mode is very poor at the two operating conditions. Incorporating the SMES unit to the generator bus will not only shift the second mode eigenvalue to the left side of the s-plane but the damping of other oscillating modes will be enhanced. The overall performance is improved with the SMES unit and the damping effect of the SMES unit to all modes is highly beneficial as can be seen from the torsion modes eigenvalue when the SMES unit is connected to the generator bus.

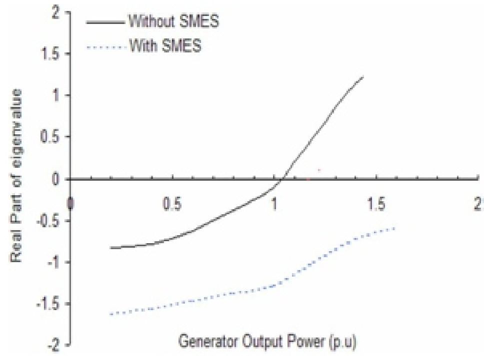

Fig.6 Real part of mode 2 eigenvalue under Different load conditions

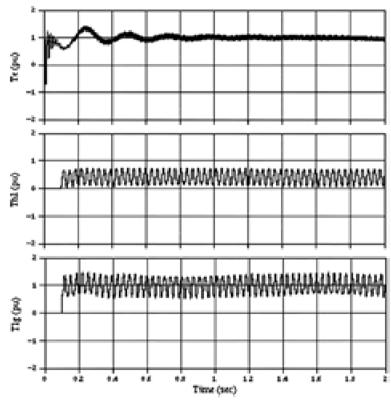

Fig. 8 Dynamic response of the generator Shaft during normal operation.

Fig. 7 shows the real part of the Eigen values of mode 2 versus active power outputs of generator without and with the SMES unit connected to the generator bus. Without the SMES unit, the system is stable up to p.u. The stability margin of the system with SMES unit connected is above p.u.

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The system stability margin is greatly increased by the SMES unit under the proposed controller.

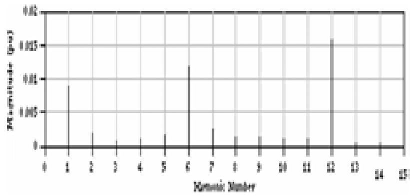

Fig. 9 Frequency spectra of T_e during normal Operation.

VII. SIMULATION RESULTS:

In all the cases studied, attention has been given to the dynamic response of the turbine-generator shaft, i.e., the electromagnetic torque, the torque on the shaft segment between high-pressure and low-pressure turbines, and the torque on the shaft segment between low-pressure turbine and generator. Time domain waveforms due to studied faults without and with the use of the SMES controller are compared. In all the cases studied, the turbine-generator is assumed to be operating at steady-state delivering rated power to the infinite-bus System when the converter station is suddenly connected to the transformer high tension bus. To verify this condition, the multi mass system has been enabled at 0.1 s.

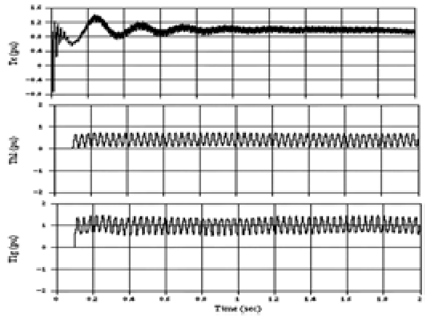

Fig. 10 Dynamic response of the generator Shaft during fire-through without SMES unit.

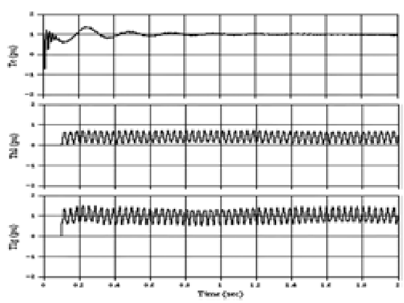

Fig. 11 Dynamic response of the generator shaft during fire-through with SMES

A. Normal Operation:

The normal operation of the HVDC converter station. The SMES unit is disconnected from the system in this study. It can be seen from the harmonic analysis of the electromagnetic waveform (shown in Fig. 9) that the turbine-generator electromagnetic torque contains harmonics of order where an integer is. There is also a unidirectional component which is attributed to the change in the system conditions (a step change in power) and it subsequently varies with the turbine-generator natural frequency of oscillation. The power frequency (60 Hz) component is due to the dc offset in the turbine generator stator currents.

B. Fire-Through:

Fire-through is the conduction of a valve having correct polarity for commutation before it's programmed instant of conduction [3]. For such fault, the firing delay angle of the faulted valve is reduced from its normal value to a smaller value or zero. Fig. 10 illustrates the dynamic response of the generator shaft during a sustained fire-through of valve of the HVDC converter station. All the valves of the converter are operating with a firing delay angle except valve which is conducting. It can be seen from Fig. 10 that such fault introduces a significant increase in the harmonic contents of the turbine-generator shaft tensional torques, which can be confirmed by comparing the harmonic analysis of the electromagneticTorque for the normal operation (Fig. 9) with that for the fire-through one (Fig. 11). Figs. 12 and 13 show, respectively, the typical dynamic response of the system.

VIII. CONCLUSION:

In this paper, a novel application of SMES unit in HVDC systems has been elaborated. Studies have been performed to investigate the effect of applying an SMES unit to an HVDC system in case of faults occurring in the converter, inverter or in the ac side. The shaft system of turbine-generator is subjected to high stresses during these faults that may lead to severe damages in the shaft. By connecting the SMES unit to the generator bus, active and reactive power modulation during the fault can be achieved smoothly, rapidly, and independently, resulting in increasing system damping and reducing the mechanical shaft torsion torques significantly. With continued research on superconducting materials, the cost of SMES is decreasing so that it will be a more commercially available and cost-competitive option than other power system stabilizers.

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