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Hybrid Series Capacitive Compensation Scheme In Damping Power System Oscillations Using Tcsc

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Abstract
This paper demonstrates the phase imbalanced series capacitive compensation concept to enhance power system dynamics as it has the potential of damping power swing as well as sub synchronous resonance oscillations. A scheme for a phase imbalanced capacitive compensation is shown. It is a *"hybrid"* series compensation scheme, where the series capacitive compensation in one phase is created using a single-phase TCSC in series with a fixed capacitor (Cc), and the other two phases are compensated by fixed series capacitors (C).

Key words: FACTS controllers, phase imbalance, series compensation, thyristor controlled series capacitor (TCSC).

I. INTRODUCTION

Flexible AC Transmission Systems (FACTS) technology provides unprecedented way for controlling transmission grids and increasing transmission capacity [1]. FACTS Controllers provide the flexibility of controlling both real and reactive power which could result in an excellent capability for improving power system dynamics . A problem of interest in the power industry at which FACTS Controllers could play a significant role in it is increasing damping of low frequency power oscillations that often arise between areas in large interconnected power networks. These oscillations are termed inter-area oscillations, which are normally characterized by poor damping [2]. Inter-area oscillations can severely restrict system operations by requiring the curtailment of electric power transfers level as an operational measure. These oscillations can also lead to widespread system disturbances, e.g. cascading outages of transmission lines and, therefore, system wide voltage collapse.

Several studies have investigated the potential of using FACTS Controllers' capability in damping inter-area oscillations. The use of Thyristor Controlled Series Capacitor (TCSC) and Static Synchronous Series Compensator (SSSC) has been the subjects of several studies evaluating their respective effectiveness in enhancing power system dynamics [3].

Series capacitive compensation is the potential risk of sub synchronous resonance (SSR), where electrical energy is exchanged with a generator shaft system in a growing manner which may result in damage of the turbine-generator shaft system .Therefore, mitigating SSR has been and continues to be a subject of research and development aiming to develop effective SSR counter measures.

The recently proposed phase imbalanced series capacitive compensation concept has been shown to be effective in enhancing power system dynamics as it has the potential of damping power swing as well as sub synchronous resonance oscillations [4]. Fig. 1 shows a scheme for a phase imbalanced capacitive compensation. It is a *"hybrid"* series compensation scheme, where the series capacitive compensation in one phase is created using a single-phase TCSC in series with a fixed capacitor (Cc), and the other two phases are compensated by fixed series capacitors (C). The TCSC control is initially set such that its equivalent compensations at the power frequency combined with the fixed capacitor yield a resultant compensation equal to the other two phases. Thus, the phase balance is maintained at the power frequency while at any other frequency, a phase imbalance is created. To further enhance power oscillations damping, the TCSC is equipped with a supplementary controller.

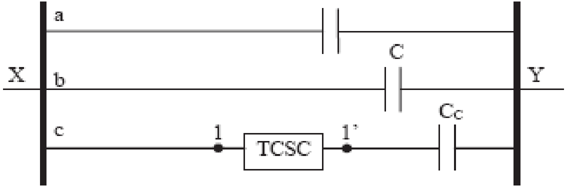


Fig.1 A schematic diagram of the hybrid series compensation scheme.

The phase imbalance of the proposed scheme can be explained mathematically as follows:
1) At the power frequency, the series reactances between buses X and Y, in Fig.1, in phases a, b, and c are given by:

$$X_a = X_b = \frac{1}{j\omega_o C} \quad (1)$$

$$X_c = \frac{1}{j\omega_o C_c} - jX_{TCSCo} \quad (2)$$

Where $-jX_{TCSCo}$ is the effective capacitive reactance of the TCSC at the power frequency such that $X_a = X_b = X_c$.

2) During any other frequency, fe

$$X_c = \frac{1}{j\omega_e C_c} - jX_{TCSCo} - j\Delta X_{TCSC} \quad (3)$$

The first two terms in (2) and (3) are different because of the difference in frequency.The third term in (3) represents the change in the effective capacitive reactance of the TCSC due to the action of the TCSC supplementary controller.

This scheme would, definitely, be economically attractive when compared with a full three-phase TCSC which has been used/proposed for power oscillations damping. Furthermore, reducing the number of thyristor valves to one third will also have a positive impact on system reliability

The effectiveness of the scheme in damping power system oscillations for various network conditions, namely different system faults and tie-line power flows is evaluated using the MATLAB simulation program and compare these results with fixed capacitive compensation scheme.

II. STUDY BENCHMARK

To demonstrate the effectiveness of the proposed scheme in power system oscillations damping, the system shown in Fig. 2 is adopted as a test benchmark. It consists of three large generating stations (G_1, G_2 and G_3) supplying two load centers (S_1 and S_2) through five 500 kV transmission lines. The two double-circuit transmission lines L1 and L2 are series compensated with fixed capacitor banks located at the middle of the lines. The compensation degree of L1 and L2 is 50%. The compensation degree is defined as the ratio $(X_C/X_L)*100\%$ for fixed capacitor compensated phases and $(XC_c+XTCSC)/X_L* 100\%$ for the hybrid compensated phase. The total installed capacity and peak load of the system are 4500 MVA and 3833 MVA respectively. Shunt capacitors are installed at buses 4 and 5 to maintain their voltages within 1±0.05 p.u. In this paper, S1 = 1400 + j200 MVA and S2 = 2400 + j300 MVA . The MATLAB is used as the simulation study tool.

III. MODELING OF THE SINGLE-PHASE TCSC

The single-phase TCSC is modeled in the MATLAB as a single module using an ideal thyristor pair and an RC snubber circuit as shown in Fig. 3. A Phase Locked Loop (PLL) is used to extract phase information of the fundamental frequency line current, which will be used to synchronize TCSC operation. The thyristor gating control is based on the Synchronous Voltage Reversal (SVR) technique[4]-[6]. The TCSC impedance is measured in terms of a boost factor k_B, which is the ratio of the apparent reactance of the TCSC seen from the line to the physical reactance of the TCSC capacitor bank. A positive value of k_B is considered for capacitive operation. A low-pass filter based estimation algorithm is used to estimate the voltage and the current phasors. A boost measurement block performs complex impedance calculations for the boost factor of the TCSC as Kb = Imag{$\hat{V}_C$ / $\hat{I}_C$ }/ X_{CTCSC} , where, $\hat{V}_C$ and $\hat{I}_C$ are the estimated phase voltage and current and X_{CTCSC} is the capacitive reactance of the TCSC capacitor branch at the fundamental frequency. A proportional-integral (PI) control based boost level controller is implemented to control the TCSC boost level to the desired value by adjusting the instant of the expected capacitor voltage zero crossing. The integral part of the controller helps in removing the steady state errors. The controller parameters were determined by performing repeated time domain simulations for the different operating conditions. This algorithm uses the difference between the actual boost level and the reference boost level (e_{rr}) shown in Fig. 3 as an objective function. The algorithm starts with arbitrary initial values for the control parameters and calculates the values of the objective function each time. The control parameters are incremented for the next iteration and the procedure is repeated until the objective function approaches a minimum value (below a threshold value). The procedure described above is widely used by industry for tuning of controller parameters.

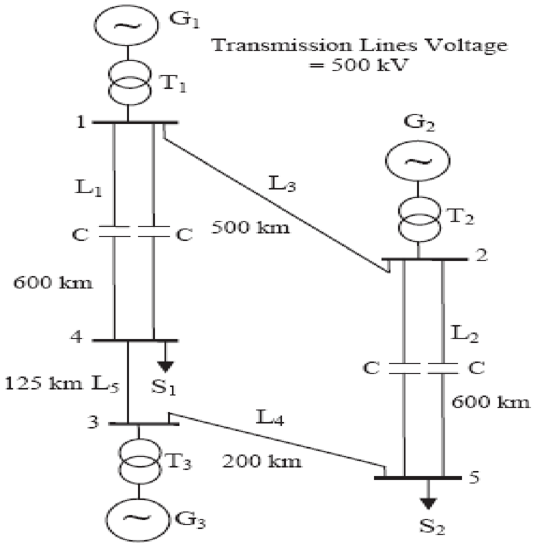


Fig. 2 Test benchmark

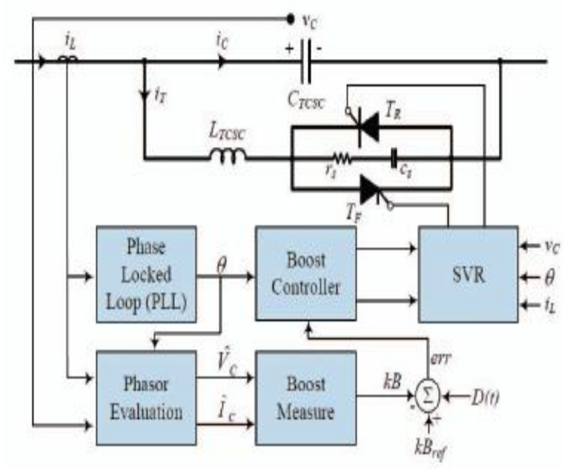


Fig. 3 Block diagram of a TCSC controller

In Fig. 3, D(t) is a supplemental signal generated from an *m*-stage lead-lag compensation based controller. As the real power flow in the transmission line is proportional to the inverse of the total line reactance, the power swing damping can be achieved by properly modulating the apparent TCSC reactance through this controller.

The supplemental controller input (stabilizing) signals could be local (e.g. real power flows) or remote (e.g. load angles or speed deviations of remote generators). If a wide-area network of Synchronized Phasor Measurement (SPM) units is available, then the remote signals can be downloaded at the controller in real time without delay. Local signals are generally preferred over remote signals as they are more reliable since they do not depend on communications.

In Fig. 3, *kBref* is the TCSC boost level set point. The Synchronous Voltage Reversal block solves for angle γ from the non-linear relation, $u_{CZ} = X_o i_{LM}[\lambda_\gamma - \tan(\lambda_\gamma)]$, where u_{CZ} is the estimated capacitor voltage at the desired instant when the capacitor voltage zero crossing occurs, i_{LM} is the measured value of the line current i_L, X_0 is the TCSC capacitor reactance at the TCSC resonance frequency, λ is the ratio between the TCSC resonance frequency and the system fundamental frequency and γ is the angle difference between the firing time and the voltage zero-crossing. The value of γ is used to calculate the exact firing instants of the individual thyristors.

IV. MATLAB/SIMULINK MODELING OF TEST STUDY.

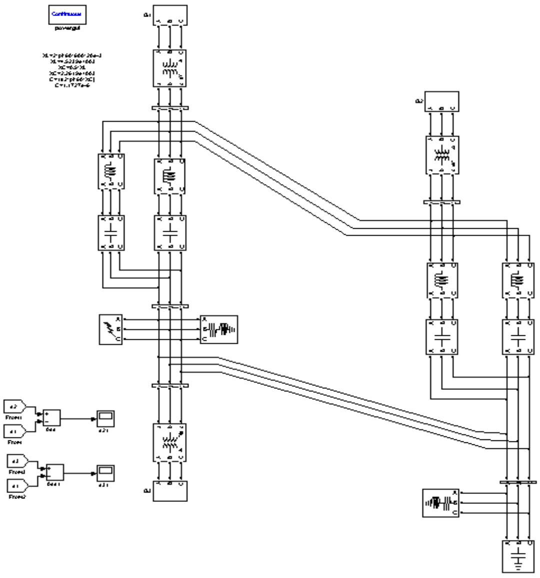


Fig. 4 Simulation diagram of Fixed Compensatin.

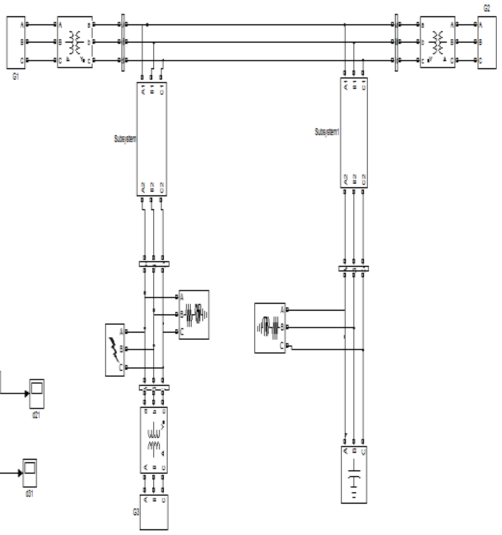
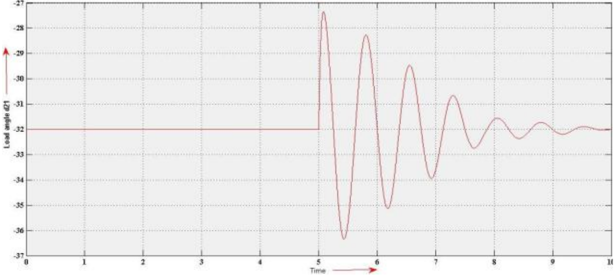
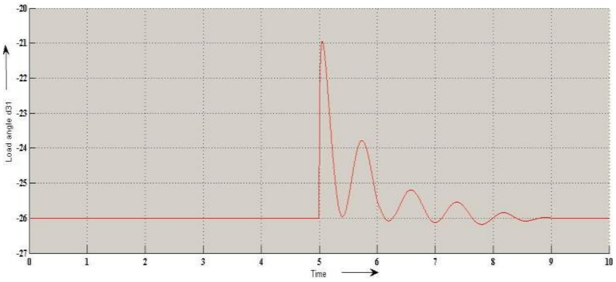


Fig. 5 Simulation diagram of the hybrid TCSC compensation scheme.

Comparing the responses of the fixed series capacitor compensation to the hybrid TCSC compensation scheme in Fig. 8, the positive contribution of the proposed hybrid scheme to the damping of the system oscillations is very clear. As it can be seen from Fig.8, the power swing damping controller effectively damps the system oscillations. It can also be seen from Fig. 9 that the best damping of the relative load angle responses are achieved with the δ_{31}-δ_{21} combination. The second best damped responses are obtained with the δ_{31}-δ_{21} combination. These results should be expected due to the direct relationship between the relative load angles and the generators that yield the problem. It can also be seen from Fig. 9 that the worst damped responses are obtained with PL1- δ_{21} combination which results also in the increase of the first swings.



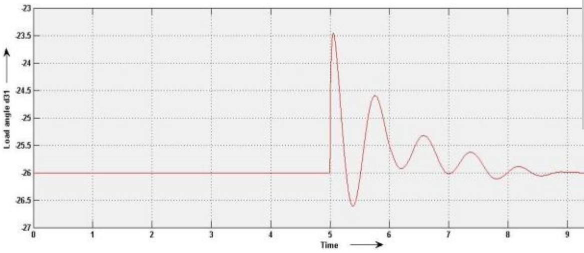
(a)



(b)

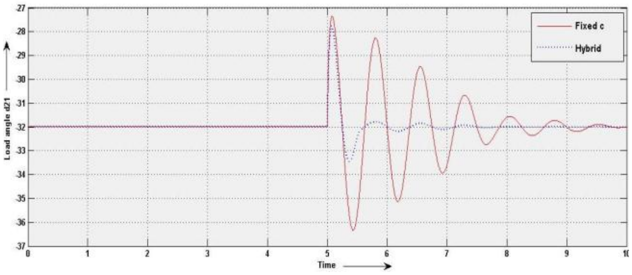
Fig. 6 Simulation results for Generator load angles, measured with respect to generator 1 load angle, during and after clearing a three-phase fault at bus 4 with fixed compensation. (a).Load angle d21. (b).Load angle d31.

(a)



(b)

Fig.7 Simulation results for Generator load angles, measured with respect to generator 1 load angle, during and after clearing a three-phase fault at bus 4 With Hybrid TCSC compensation. (a).Load angle d21. (b).Load angle d31.



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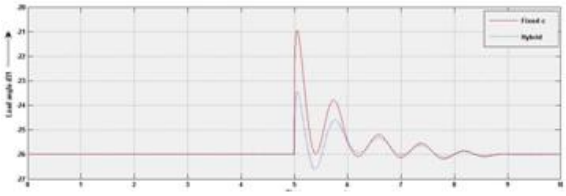
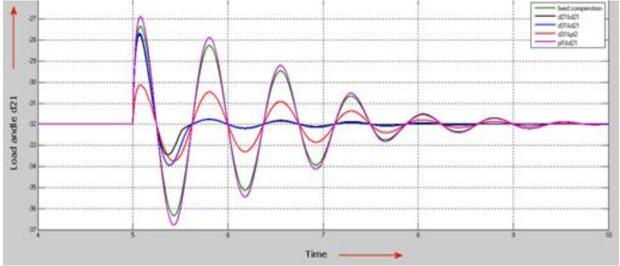
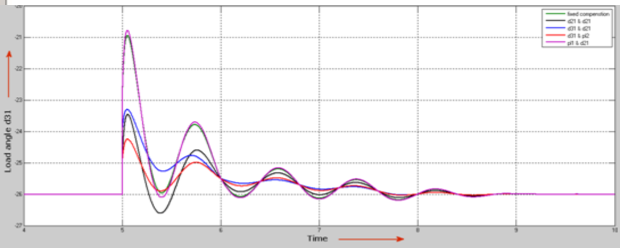


(b)

Fig.8 Comparing the Simulation results of Generator load angles, measured with respect to generator 1 load angle, during and after clearing a three-phase fault at bus 4.With fixed compensation and Hybrid TCSC compensation. (a).Load angle d21. (b).Load angle d31.



(a)



(b)

Fig.9 Simulation results for Generator load angles, measured with respect to generator 1 load angle, during and after clearing a three-phase fault at bus 4. (a).Load angled21.(b).Load angle d31.

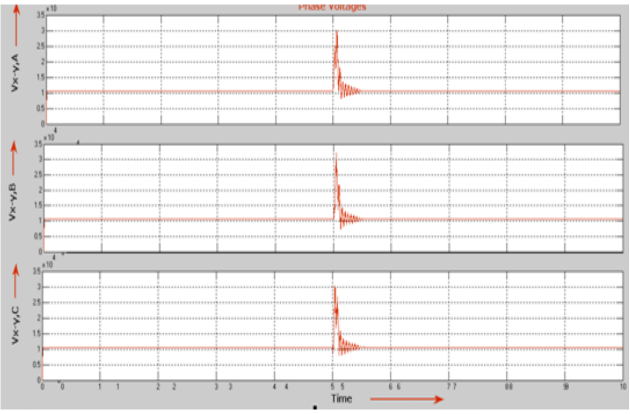


Fig.10 Phase voltages, VX-Y across the hybrid single-phase-TCSC scheme on L1 during and after clearing a three-phase fault at bus 4

V. CONCLUCTION

In this paper the application of a new hybrid series capacitive compensation scheme in damping power system oscillations has been elaborated. The effectiveness of the presented scheme in damping these oscillations is demonstrated through several digital computer simulations of case studies on a test benchmark. The presented hybrid series capacitive compensation scheme is feasible, technically sound, and has an industrial application potential.

Flexible AC Transmission Systems (FACTS) technology provides unprecedented way for controlling transmission grids and increasing transmission capacity FACTS Controllers provide the flexibility of controlling both real and reactive power which could damping oscillations. This presented hybrid series capacitive compensations scheme can be improved by choosing proper compensation scheme for TCSC that can reduce time to minimize the fault and control the real and reactive power.

REFERENCES

[1] Narain G. Hingorani and Laszlo Gyugyi, “Understanding FACTS, Concepts and Technology of Flexible AC Transmission Systems,” IEEE Press, 2000

[2] M. Klein, G.J. Rogers and P. Kundur, “A Fundamental Study of Inter-Area Oscillations in Power Systems,” IEEE Transactions on Power Systems, Vol. 6, No. 3, 1991, pp. 914-921.

[3] E.V. Larsen, J.J. Sanchez-Gasca and J.H. Chow, “Concepts for Designof FACTS Controllers to Damp Power Swings,” IEEE Transactions on Power Systems, Vol. 10, No. 2, May 1995, pp. 948-956.

[4] B. Chaudhuri, B. Pal, A. C. Zolotas, I. M. Jaimoukha, and T. C. Green,“Mixed-sensitivity Approach to H Control of Power System Oscillations Employing Multiple FACTS Devices,” IEEE Transactions on Power System, Vol. 18, No. 3, August 2003, pp. 1149–1156.

[5] B. Chaudhuri and B. Pal, “Robust Damping of Multiple Swing Modes Employing Global Stabilizing Signals with a TCSC,” IEEE Transactions on Power System, Vol. 19, No. 1, February 2004, pp. 499–506.

[6] D. Rai, G. Ramakrishna, S.O. Faried and A. Edris,” Enhancement of Power System Dynamics Using a Phase Imbalanced Series Compensation Scheme,” IEEE Transactions on Power Systems, Vol. 25,No. 2, May 2010, pp. 966-974.

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