DAMPING OF SUB SYNCHRONOUS RESONANCE OSCILLATIONS DUE TO TORSIONAL INTERACTION USING A DYNAMIC SSSC SCHEME

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ABSTRACT

The manuscript presents a new effective method to damping Sub Synchronous Resonance (SSR) – shaft torsional oscillations for synchronous generators. The proposed scheme with a dynamic 3 φ PWM SSSC and Power Oscillation Damping controller can be achieved damping of SSR oscillation. This method is based on using the SSSC to inject unbalanced series quadrature voltages and unbalanced shunt reactive currents in transmission line just after clearing faults. When the sub synchronous oscillations drive unsymmetrical phase currents, the developed electromagnetic torque will be lower than the condition when the three-phase currents are symmetrical. The unsymmetrical currents result in a lower coupling strength between the mechanical and the electrical system at asynchronous oscillations. Therefore, the energy exchange between the electrical and the mechanical systems at sub synchronous oscillations will be suppressed, thus, avoiding the build-up of torsional stresses on the generator shaft systems under sub synchronous resonance condition.

Keywords: Torsional Oscillation, SSR Mitigation, SSSC, Power Oscillation Damping controller

I. INTRODUCTION

Most electrical networks are widely interconnected for economic reasons – optimum sharing of electrical power, optimum utilization of resources and deregulation of electric market. Bulk power is transmitted to the load centre via transmission lines connected to the most economic sources generally located far away from the load centre. The operation of ac transmission lines is generally constrained by limitations of one or more network parameters (e.g. line impedance) and operating variables such as voltages and currents. As a result, a transmission line may not be able to transfer the required power demand and there may be a necessity to build a costly parallel transmission line. The optimal use of existing system may be overcome the costly construction of parallel transmission lines. The cost-effective tool for optimum/economical use of transmission line and improving system stability and power flow through medium and long ac transmission line is the use of series capacitor compensation [1].

Series capacitor-compensated transmission lines eliminate the need for building parallel transmission lines. Although it is the cheapest means to achieve higher power transfer, it has a potential adverse impact. The possible adverse interaction between the capacitor and the turbine generator was reported in 1937 [2]. Two successive shaft failures were reported in the Mohave generating station in 1970 and 1971 in Nevada, USA because of this problem [3]. The build-up of such torsional torque oscillations in the multi-mass turbine-generator system following a disturbance in a series capacitor compensated transmission line is termed as Sub Synchronous Resonance (SSR).

The application of FACTS and HVDC technologies, in the form of Voltage Sourced Converter (VSC) based designs, continue to be implemented throughout the world for improved transmission system control and operation. FACTS and HVDC-link technologies allow more efficient utilization of existing transmission networks and help to better facilitate needed transmission system expansion [4,5,6,7]. The wide-scale application of these technologies leads to numerous benefits for electrical transmission system infrastructure, including increased capacity at minimum cost; enhanced reliability through proven performance; higher levels of security by means of sophisticated control & protection; and improved system controllability with state-of-the-art technology concepts. Both conventional and advanced forms of FACTS and HVDC transmission technologies exist and are in operation today. Advanced solutions are in the form of VSC based designs, including configurations for Static Synchronous Compensators (STATCOM), Unified

Power Flow Controllers (UPFC), Static Synchronous Series Compensators (SSSC), and others. In this paper, the proposed scheme with a dynamic 3 φ PWM SSSC and Power Oscillation Damping controller can be achieved damping of SSR oscillation.

II. SAMPLE STUDY SYSTEM

As the SSSC does not use any active power source, the injected voltage must stay in quadrature with line current. By varying the magnitude Vq of the injected voltage in quadrature with current, the SSSC performs the function of a variable reactance compensator, either capacitive or inductive. The variation of injected voltage is performed by means of a Voltage-Sourced Converter (VSC) connected on the secondary side of a coupling transformer shown in fig 1.

The VSC uses forced-commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize a voltage V_conv from a DC voltage source. A capacitor connected on the DC side of the VSC acts as a DC voltage source. A small active power is drawn from the line to keep the capacitor charged and to provide transformer and VSC losses, so that the injected voltage Vs is practically 90 degrees out of phase with current (I). In the control system block diagram (fig 2) Vd_conv and Vq_conv designate the components of converter voltage V_conv which are respectively in phase and in quadrature with current. Two VSC technologies can be used for the VSC: VSC using GTO-based square-wave inverters and special interconnection transformers. Typically four three-level inverters are used to build a 48-step voltage waveform. Special interconnection transformers are used to neutralize harmonics contained in the square waves generated by individual inverters. In this type of VSC, the fundamental component of voltage V_conv is proportional to the voltage Vdc. Therefore Vdc has to varied for controlling the injected voltage.VSC using IGBT-based PWM inverters. This type of inverter uses Pulse-Width Modulation (PWM) technique to synthesize a sinusoidal waveform from a DC voltage with a typical chopping frequency of a few kilohertz. Harmonics are cancelled by connecting filters at the AC side of the VSC. This type of VSC uses a fixed DC voltage Vdc. Voltage V_conv is varied by changing the modulation index of the PWM modulator. The SSSC (Phasor Type) block models an IGBT-based SSSC (fixed DC voltage). However, as details of the inverter and harmonics are not represented, it can be also used to model a GTO-based SSSC in transient stability studies.The control system consists of A phase-locked loop (PLL) which synchronizes on the positive-sequence component of the current I. The output of the PLL (angle $\Theta = \omega t$) is used to compute the direct-axis and quadrature-axis components of the AC three-phase voltages and currents (labeled as Vd, Vq or Id, Iq on the diagram).Measurement systems measuring the q components of AC positive-sequence of voltages V1 and V2 (V1q and V2q) as well as the DC voltage Vdc.AC and DC voltage regulators which compute the two components of the converter voltage (Vd_conv and Vq_conv) required to obtain the desired DC voltage (Vdcref) and the injected voltage (Vqref). The Vq voltage regulator is assisted by a feed forward type regulator which predicts the V_conv voltage from the Id current measurement.

III. SAMPLE MATLAB/SIMULINK RESULTS

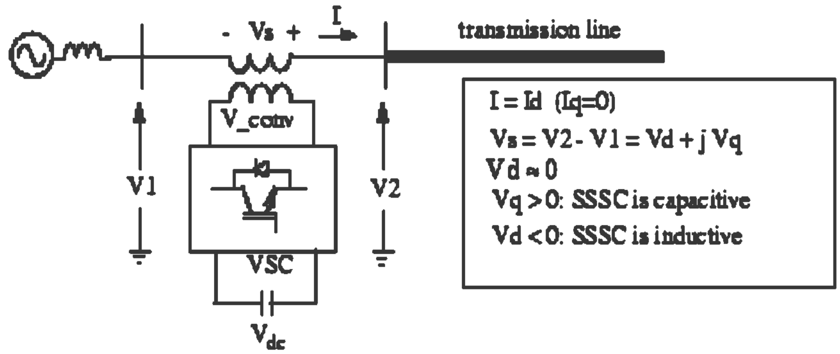

Fig. 1. SSSC block diagram

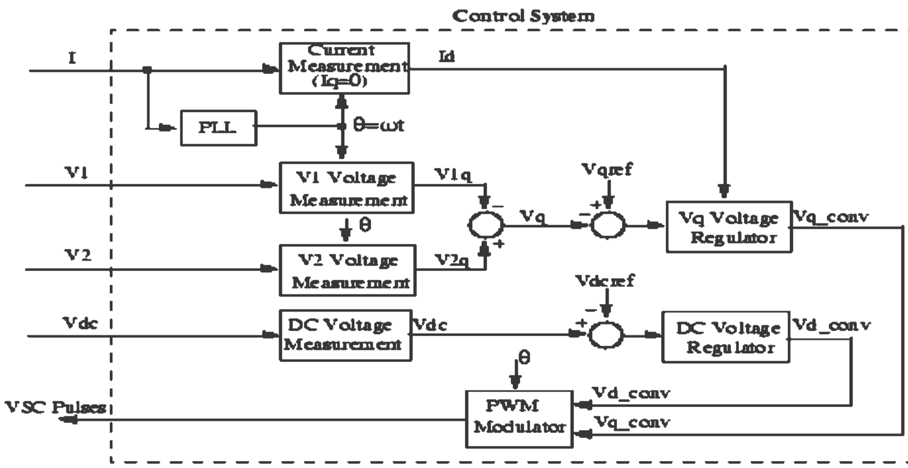

Fig. 2. Control system block diagram for SSSC.

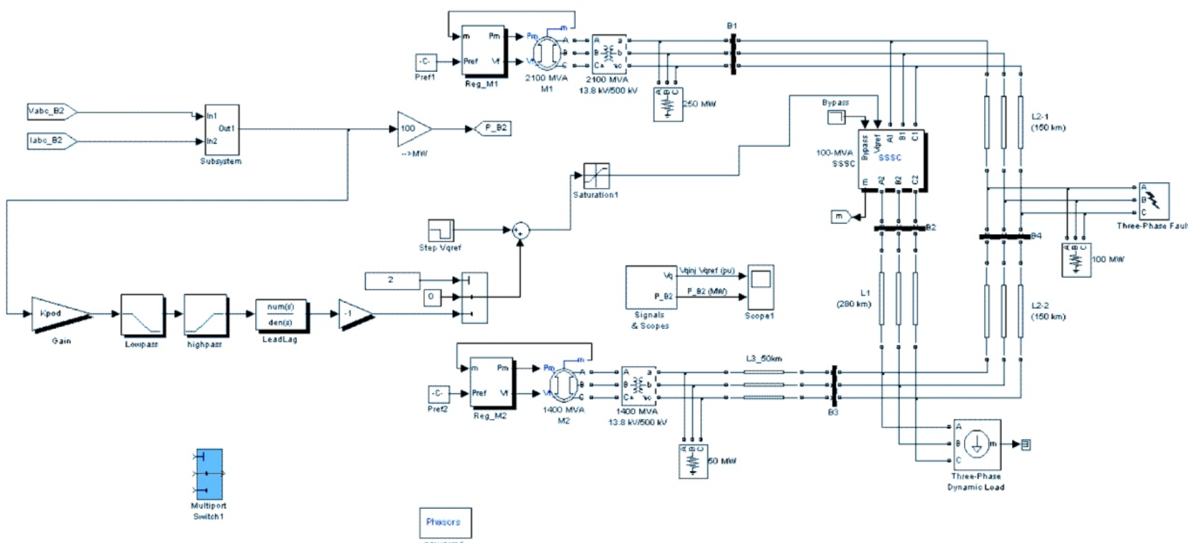

Fig 3: MATLAB/SIMULINK Unified Block Functional Model of the SSSC used to study SSR-oscillations following a three phase bolted short circuit fault with Lead Lag compensator.

Without SSSC control :

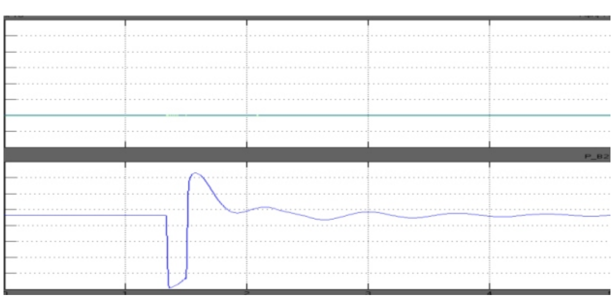

Fig. 4. SSR produced in Model in case SSSC is by passed by fault generation.

With SSSC:

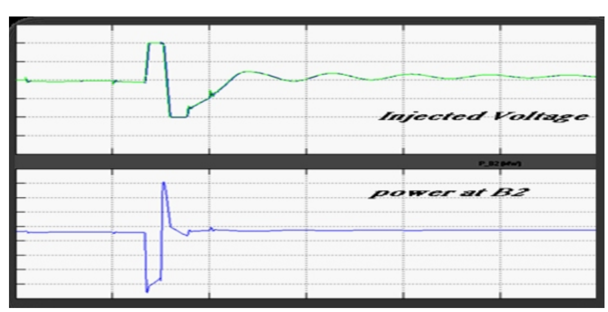

Fig. 5. SSR damped in Model in case SSSC is used and SSSC inject the voltage.

In figure 4 and figure 5 fault is created manually to understand the sub synchronous damping without and with SSSC. In figure 5 SSSC injected the voltage. The sub-synchronous oscillation shown in figure 5 is reducing greatly using voltage injection through the SSSC controller. The amplitude of oscillation decrease by 15% and damping time is reducing to 20%.

In figure 6 and figure 7 represents SSR power oscillation damping without and with Lead lag network compensator. In figure 7 improvements is observed in term of peak oscillation amplitude and damping time. The amplitude of oscillation decrease by 5% and damping time is reducing to 15%.

IV. CONCLUSION

This paper presents a new method to damp subsynchronous resonance (SSR) oscillations for large synchronous generators. The damping signals using stator current and voltage is easy to implement and significantly reduce the cost. The SSSC is widely used as an effective SSR damping tool that dynamically detunes the SSR-resonance model by the PWM-switching of the combined blocking series and shunt tuned arm filter.

V. REFERENCES

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Without Lag compensator:

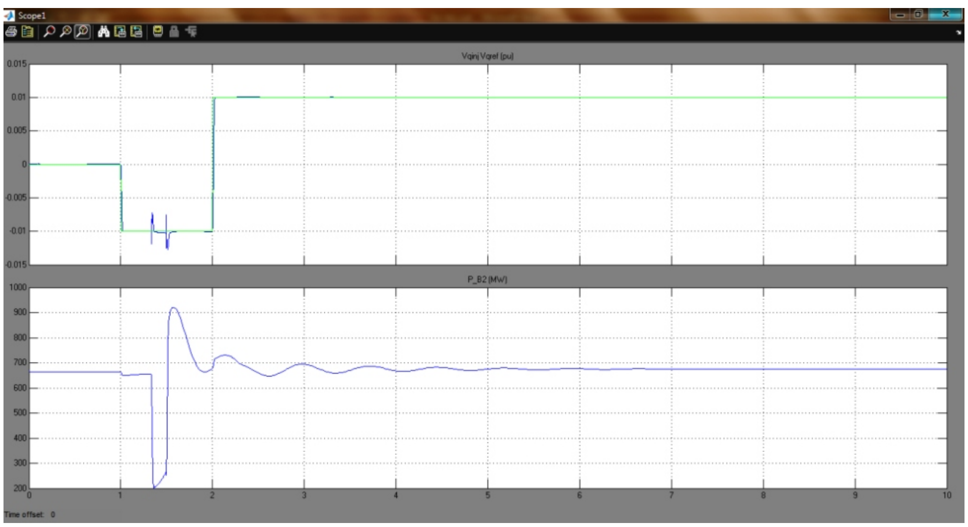

Fig. 6. SSR produced in Model in case Lead lag compensator is by passed by fault generation.

With Lead Lag compensator:

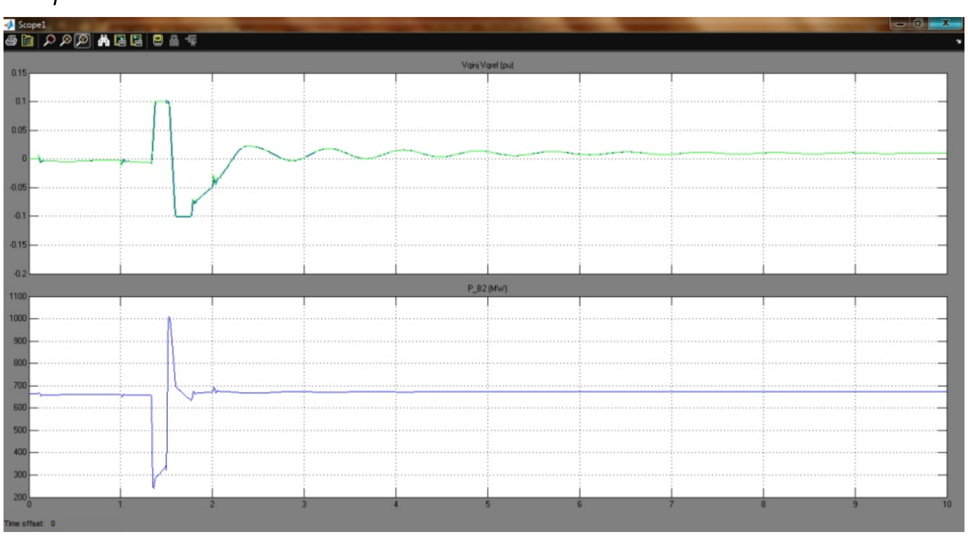

Fig 7: SSR damped in Model in case Lead lag compensator is used.

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