SIMULATION AND MITIGATION OF SSR BY SSSC AS FACTS DEVICE WITH LEAD LAG COMPENSATOR

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ABSTRACT

In this manuscript, a narrative Simulink® simulation model for simulation of Sub-Synchronous Resonance (SSR) and mitigation of SSR by the help of lead lag compensator as controller with Static Synchronous Series Compensator will be anticipated. Simulink® model deals simulation of the SSR in transmission line network. This manuscript is to derive a model with SSSC with lead lag compensator in between electrical transmission line and SSSC. This model is used to mitigation of SSR by using stator current and voltage signals of synchronous generator as damping signals. In SSR, Sub-synchronous frequency may interact with one of the natural torsional modes of the turbine-generator shaft, thereby this model setting up the conditions for an exchange of the energy at a sub synchronous frequency, with possible torsional fatigue damage to the turbine-generator shaft.

KEYWORDS: SSR, Static Synchronous Series Compensator (SSSC), Lead Lag Compensator

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I. INTRODUCTION

This manuscript is derived a model with Static Synchronous Series Compensator (SSSC) with lead lag compensator as controller in between electrical transmission line and SSSC. Sub-synchronous frequency may interact with one of the natural torsional modes of the turbine-generator shaft, thereby this model setting up the conditions for an exchange of the energy at a sub synchronous frequency, with possible torsional fatigue damage to the turbine-generator shaft. Due to generation of sub-synchronous resonance (SSR) especially in electric grid networks with heavily series compensated transmission lines, shaft mechanical systems for large synchronous or induction motors and turbine generators can be subjected to severe torsional stresses. Torsional oscillations exhibit a complex electro-mechanical resonance sustained phenomena which can seriously damage the mechanical shaft system. Working Group of IEEE-SSR has been proposed IEEE benchmark models for SSR [1-2]. Literature reveals that these benchmark models are extensively used for the study of different proposed damping devices SSR counter measures [3-10]. In this manuscript, stator current and voltage signals of synchronous generator are used as damping signals. In this novel anticipated model damping signals are used to activate Static Synchronous Series Compensator as isolation and damping devices.

This manuscript reveals evadement of system sub-synchronous resonances at below the fundamental frequency as lead lag compensator controller is used. It reduces the steady state error means reduces vibration amplitude of hydraulic turbine generator rotor as well as mitigate the negative sequence components and protect power system from instability. Mashhood H., Shiksha B., and Naimul, H. [11] were earlier representing a method of analysis and mathematical modeling of sub-synchronous resonances (SSR) to mitigation of torsional interaction by passive lag compensator. Shiksha, B. etal.; represented analysis and mathematical modeling of sub-synchronous resonance mitigation using
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II. SIMULATION AND MODELING

The purpose of simulation of sub synchronous resonance in simulink® is to simulate SSR in transmission line. Simulink® model for SSR is shown in Figure 1. When fault in phase A or phase B or phase C creates a load misbalance and produces damped SSR. Figure 2 depicts the hydraulic turbine generator and shaft system functional model.

Figure 1 : Schematic SIMULINK simulation model for SSR generation

Figure 2 : Schematic SIMULINK simulation model for power generation substation

passive lag compensator through soft computing techniques in AICTE sponsored National Conference on Soft Computing Techniques in Electrical Engineering (SCTEE) [12].
Matlab/Simulink model for damping SSR is shown in fig 3. Fig 3 depicts components of model along their properties. The power grid consists of two power generation substations and one major load center at bus B3. The first power generation substation (M1) has a rating of 2100 MVA, representing 6 machines of 350 MVA and the other one (M2) has a rating of 1400 MVA, representing 4 machines of 350 MVA. The load center of approximately 2200 MW is modeled using a dynamic load model where the active & reactive power absorbed by the load is a function of the system voltage. When the SSSC is bypass, the power flows towards this major load are given in Table I.

**Table I : Power Flows towards Major Load**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Flow</th>
<th>Transmission Line</th>
<th>Measured at Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>664</td>
<td>L1</td>
<td>Bus B2</td>
</tr>
<tr>
<td>2</td>
<td>563</td>
<td>L2</td>
<td>Bus B4</td>
</tr>
</tbody>
</table>

The SSSC, located at bus B1, is in series with line L1. It has a rating of 100MVA and is capable of injecting up to 10% of the nominal system voltage. This SSSC is a phasor model of a typical three-level PWM SSSC. Proposed model represents a SSSC having a DC link nominal voltage of 40 kV with an equivalent capacitance of 375 uF. On the AC side, its total equivalent impedance is 0.16 pu on 100 MVA. This impedance represents the transformer leakage reactance and the phase reactor of the IGBT bridge of an actual PWM SSSC. The SSSC injected voltage reference is normally set by a lead lag compensator controller whose output is connected to the $V_{qref}$ input of the SSSC. The lead lag compensator controller consists of an active power measurement system, a general gain, a low-pass filter, a washout high-pass filter, a lead compensator, and an output limiter. The inputs to the lead lag compensator controller are the bus voltage at B2 and the current flowing in L1.
III. RESULTS & DISCUSSIONS

i) SSR Simulation Results

Figures 4 and 5 show response for Sub synchronous resonance which is simulated in figure 1 by SIMULINK® model. The fault in phase A or phase B or phase C creates a load misbalance and produce damped SSR. Fig 4 displays measured voltage during SSR. Fig 5 displays respective power signals with voltage measured in fig 4.

Figures 3-4 (Page 69-70)
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Figure 5: SSR simulation results by SIMULINK® in measured voltage.

ii) SSSC Dynamic Response without lead lag compensator

For obtaining of dynamic response, model is programmed to modify the reference voltage $V_{qref}$ as per values are given in table II.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Time (sec)</th>
<th>$V_{qref}$ (pu)</th>
<th>Lead Lag Compensator as Controller</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>off</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>-0.08</td>
<td>off</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>0.08</td>
<td>off</td>
</tr>
</tbody>
</table>

Figure 6: SIMULINK® block representation shows active power measurement

Figure 6 shows active power measurement and its linear mean value output from two inputs. Figure 7 shows dynamic response of model without lead lag compensator according to parameters given in table II.
In Figure 7, represent the $V_{qref}$ signal (magenta trace) along with the measured injected voltage and active power flow ($P_{B2}$) on line L1, measured at bus B2 by SSSC. Here SSSC regulator follows very well the reference signal $V_{qref}$. Depending on the injected voltage, the power flow on line varies from 200 to 925 MW. The power oscillation on the active power should now be very small.

iii) SSSC damping power oscillation with lead lag compensator

Operations of SSSC with lead lag compensator, in case $V_{qref}$ variations are disabled and switching on phase A, B and C to simulate a three-phase fault. Response is shown in figure 8.
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When lead lag compensator is operated as controller in model. Second graph of figure 7 shows that the SSSC with a lead lag compensator controller is a very effective tool to damp power oscillation without lead lag compensator controller.

The amplitude of power oscillations are in fig 7 is 200 to 925 MW while in fig 8 are 250 to 1000 MW. The damping time reduces in fig 7 is upto 4.5 sec while in fig 8 is 2 sec. Derived responses of fig 7 and 8 evidently shows that damping time and amplitude of oscillation is drastically reduced by SSSC with lead lag compensator controller.

IV. CONCLUSIONS

This novel work presents a narrative method to damp sub synchronous resonance (SSR) oscillations for large synchronous generators. Stator current and voltage is easy to implement as damping signals and significantly reduce the cost. This manuscript also concludes advantages over previous developed model by author himself of sub-synchronous resonance. This work produces reduction in torsional interactions between electrical and mechanical system i.e. shaft. Moreover, this manuscript reveals future enhancements by using soft computing methods to control the instability of power system.

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REFERENCES


