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Optimal Placement of SSR Damping Controller for Sub-Synchronous Resonance Phenomenon

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Abstract: In power Systems the Turbine-Generator set will have a torsional natural frequencies due to their physical properties of their multi-element shaft especially in a power generation by means of steam turbines .In transmission lines a capacitors is used as a reactive power compensating device .But the Placement of capacitors as a series compensation in AC transmission system will produce a resonance with Torsional Oscillation below the nominal frequency of the line. This phenomenon is known as sub-synchronous resonance phenomenon and it affects the shaft of the system. Thus the stability of the system is affected which is shown by a torque amplification and this phenomenon could be mitigated by using the controller .Here, the sub-synchronous resonance is analyzed and the mitigation method by using the controller is designed using MATLAB and the analysis is performed using PSCAD software.

Key words: Torsional oscillation · Sub-Synchronous Resonance · Turbine-Generator set · Damping controller

INTRODUCTION

In the last decade the penetration of renewable energy has been in trend for generating power. The purpose is to transmit a quality power and to satisfy the load without any interruption. However the steam plant contribute most of the power generation in the last decade. They produce almost 70% of the total power generation. But the turbine involved in steam power plant involves a complicated design with multi-mass shaft thereby producing a disturbance to the shaft of the system. This disturbances will grow as an oscillation thus disturbing the stability of the system also [1]. But in this steam turbine involving multi-mass produces torsional oscillation where each of the individual mass moves at different speed. This phenomenon is mainly due to a condition known as sub-synchronous resonance damaging the shaft of the system in a series compensated system .The series compensated systems are mainly the capacitors placed in a transmission line for transmitting the power over long distances. However any fault in the system will produce a resonance which is less than the nominal frequency. This phenomenon is known as the sub-synchronous resonance phenomenon.

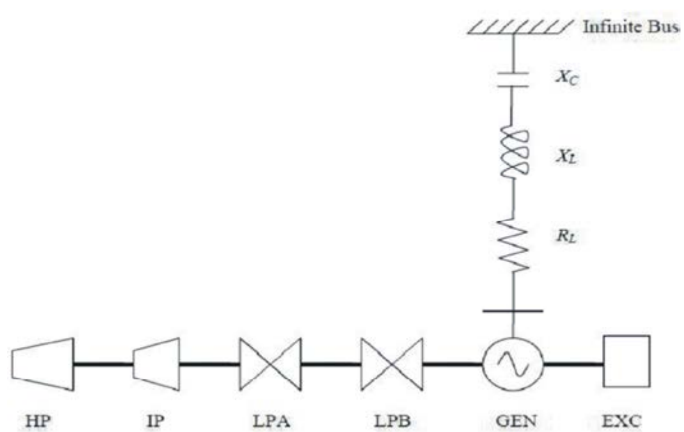

Fig. 1: Single machine infinite bus system

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Sub-Synchronous Resonance: An SSR event corresponds to an oscillation between the electric grid and the turbine–generator shaft which are at a frequencies below the synchronous frequency of the grid. These events were first detected at the Mohave power plant in Nevada, U.S.A., in the 1970's. Since then, the SSR phenomenon have been extensively studied to understand, avoid and mitigate in case of occurrence of introducing sub-synchronous resonance [3]. In general, any system capable of exchanging energy at frequencies below the rated frequency is considered a potential source of SSR excitation. The most common case occurs in the series–compensated transmission lines, where the interaction between the capacitor's capacitance and the transmission line's inductance which will introduce a natural frequency of resonance .SSR events are usually classified into two different groups depending on the systems participating in the interaction. They are known as the induction generator effect (IGE) and the torsional interaction (TI). IGE can take place when the rotor resistance (which is seen negative because the rotor rotates faster than the magnetic field) is larger than the sum of the armature and network resistances at a resonant frequency. This case leads to self–excitation increasing the voltages and currents delivered to the grid. The resonant mode for a lossless series–compensated transmission line, *fn*, can be computed using (1).

$$f_n = f_0\sqrt{\sum X_c / \sum X_L} \quad (1)$$

where,
ΣXC and ΣXL represents, respectively, the total capacitive and the total inductive reactance of the transmission line and $f0$ is the nominal system frequency.

Analysis of Sub-Synchronous Resonance: The time domain simulation of the Sub-synchronous resonance Phenomenon is been made by using the PSCAD software. The PSCAD is a useful software to view the oscillation in the system after the system is being perturb. Here perturb is made with a fault to a system. Hence the stability of the system is seen until a fault is given .But after a fault is been applied the system especially the rotor of the synchronous machine will grew its oscillation thereby the turbine coupled to it will also rotate in different speed thus producing the torsional oscillation which shows impact on the damage of the shaft which can be seen with the torque amplification.

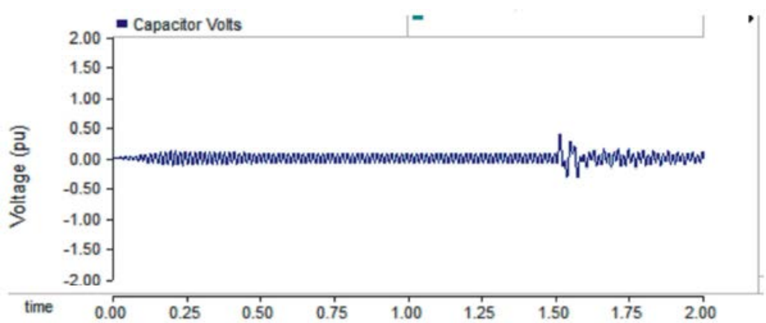

Fig. 2: Capacitor voltage after fault at 1.5 sec

Fig. 3: Effect of torque after the fault

Root Locus Technique for Damping Oscillation: Any physical system is represented by a transfer function in the form to find the pole and zeroes. The location of poles and Zeros are desirable to view stability, relative stability, transient response and error analysis. When the system put to service stray inductance and capacitance get in to the system, thus changing the location of poles and zeros. In root locus technique the placements of poles and zeros is used to damp out the oscillation to the desired reference value.

$$G(s) = k \times \frac{mumerator\ of\ s}{denomenator\ of\ s}$$

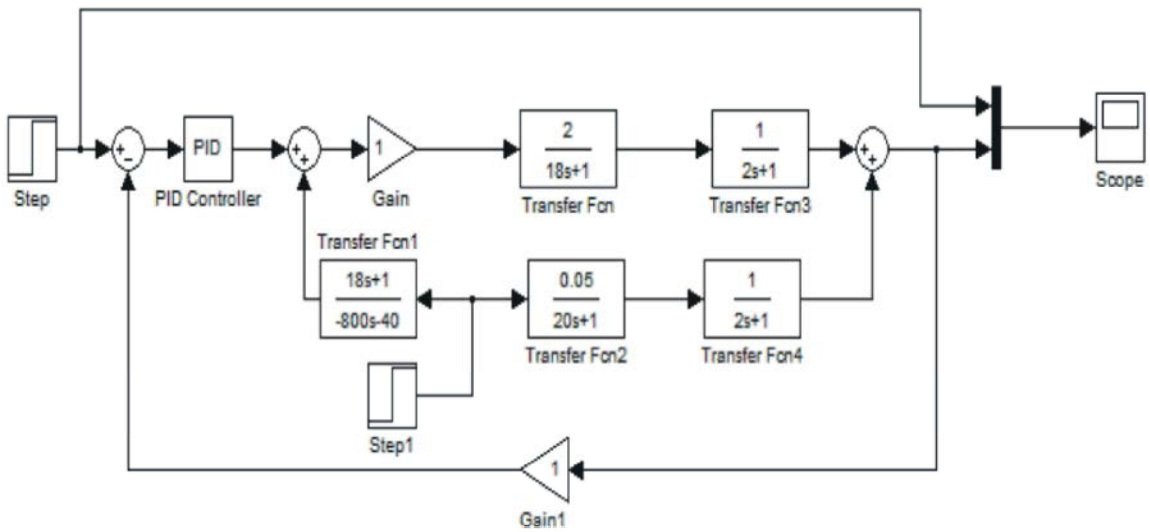

Fig 4: root locus analysis of a system

Simulation: This system is used to study the sub-synchronous resonance and particularly torque amplification after a fault on a series-compensated power system. It consists of a single generator (600 MVA/22kV/50 Hz/3600 rpm) connected to an infinite bus via two transmission lines, one of which is 55% series-compensated [2]. The sub-synchronous mode introduced by the compensation capacitor and a three-phase fault has been applied to the system and it excites the oscillatory torsional modes of the multi-mass shaft and the torque amplification phenomenon can be observed as;

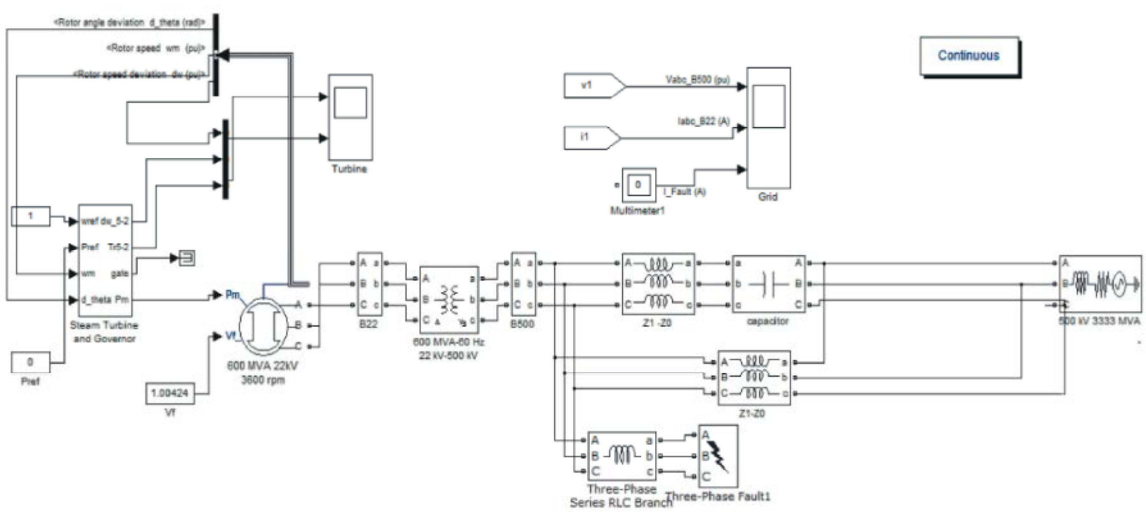

Fig. 5: Simulation for sub synchronous resonanase

RESULT AND DISCUSSION

The below graph shows the sub-synchronous resonance phenomenon. The torque amplification of the system before and after the fault is simulated as below

Without perturb

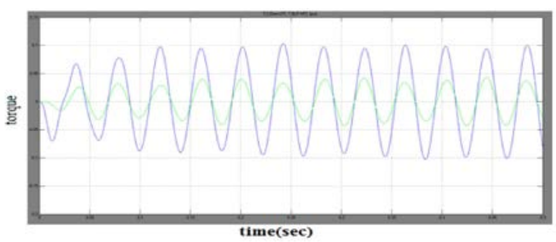

Fig. 4: Simulation of time vs torque T2(gen-lp)T3(hp-lp)

With perturb

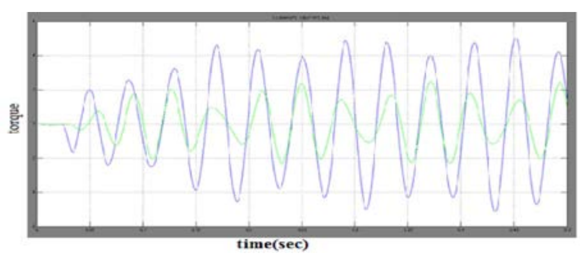

Fig. 5: Simulation of time vs torque T2(gen-lp)T3(hp-lp)

Similarly the torque amplification of the turbine and generator set is shown above with the indication the loss of synchronism in the system. The toque oscillation grew to 2pu after the fault is being applied and cleared. Thus the stability of the system is analyzed by considering the location of poles and zeros by using root locus technique.

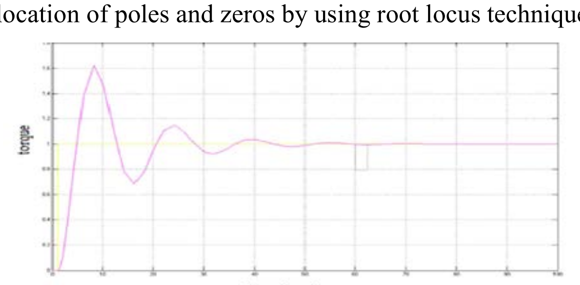

Fig. 6: Effect of controller

CONCLUSION

Thus the modelling of a system for sub-synchronous resonance is made using MATLAB. Then analysis of the ssr is made using the PSCAD software. Thus the analysis of the system before and after perturb is been simulated. From this simulation results it is shown that the system oscillates due to the SSR mode when the line is series compensated. Then, to mitigate this SSR, an SSRDC is designed using a controller .Thus the stability of the system is analyzed using the location of the poles and zeros of the system which is given by the transfer function block in the designed controller. For finding the location of poles and zeros a root locus technique is used which makes the system to damp out the oscillation. Thus the mitigation of the sub-synchronous resonance is made using a controller.

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