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Design Of Sub Synchronous Damping Controller (SSDC) For TCSC To Improve Power System Stability Of A Transmission Line.

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ABSTRACT : *The series capacitor compensation of a transmission line can be plunged into the fatigue called Sub synchronous resonance (SSR) when the capacitor which in series resonates with transmission line's total circuit inductance. The thyristor controlled series capacitor (TCSC) which improves transmission line capacity can also efficiently useful in damping out Sub synchronous resonance (SSR) effect. The SSR can be mitigated with an appropriate gating pulse to TCSC. Here in this paper, a three phase to ground fault is introduced into the system as a result the undesirable SSR started interfering. In order to detect this SSR, sub synchronous damping controller (SSDC) is designed .SSDC perceives this SSR phenomena and it directs an appropriate control signal to the TCSC. The robust TCSC's internal strategy worked out well according to the control signal and succeeded in damping out SSR.*

KEYWORDS:*Sub synchronous damping controller(SSDC),Sub synchronous resonance(SSR), Thyristor controlled series capacitor (TCSC)*

I. INTRODUCTION

The fundamental Thyristor controlled series capacitor (TCSC) strategy was proposed by Vithayathil along with others in 1986 which serves for rapid adjustment of network impedance [1]. It is composed of a capacitor for series compensation and it is shunted by a thyristor controlled reactor (TCR) shown in Figure.1.The main theme of the TCSC approach is to yield a continually varying capacitor by moderately negotiating the compensating capacitancewith the assistance of TCR. Not only a TCSC is advantageous in increasing the power transfer capability by compensating reactance of the line but also in damping out SSR [2].With the help of analog simulator it is shown that electrical damping furnished by TCSC virtually identical as one that is of no compensation, which mean TCSC is neutral to SSR[3].The manifestation of field tests at Slatt substation reveals that TCSC doesn't take part in SSR[4].Relying on Poincare mapping, some dynamic models has been derived and they are useful for SSR's Eigen value analysis[5]-[8].If the thyristors conduction angle is wide enough, then the capacitor is bypassed by thyristor switches (SW) for such wide conduction angle and SSR will be unseen. Yet when the firing angle approaches to 1800 and angle of conduction becomes restricted, the performance of TCSC is close to the series capacitor and a large negative damping is shown accordingly. If the generator possess modest damping characteristics, SSR may not occurs. So, the modulation of firing angle of TCSC comes into act, when conduction angle is narrow or when generating machines doesn't possess moderate damping characteristics [2].While performing field test [5],signals of speed of the rotor is chosen to modulate the firing angle of TCSC in order to excite the torsional oscillation modes .In this paper, a sub synchronous damping controller(SSDC) is designed to recognize SSR. The rotor speed deviation is the only input to SSDC. Firstly the information regarding the SSDC design is conveyed and in the next section results which obtained for a three phase fault to ground with and without SSDC is manifested.

II. SYSTEM UNDER STUDY

The first system of IEEE bench mark model is employed to assess and scrutinize the menace of SSR [9].In this system. A 600MVA synchronous machine along with two transmission lines is connected to a infinite bus. This is shown in Figure.2.

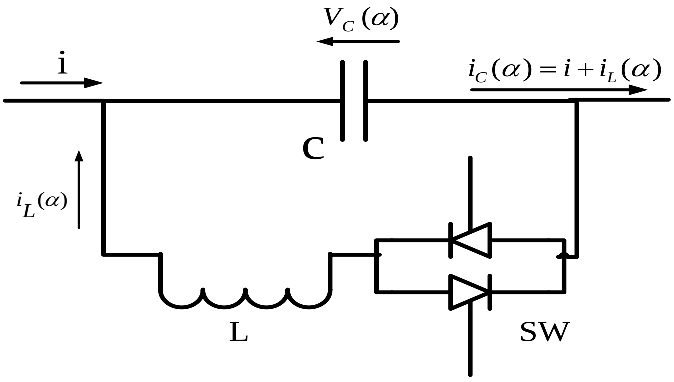

Fig.1 Fundamental TCSC block

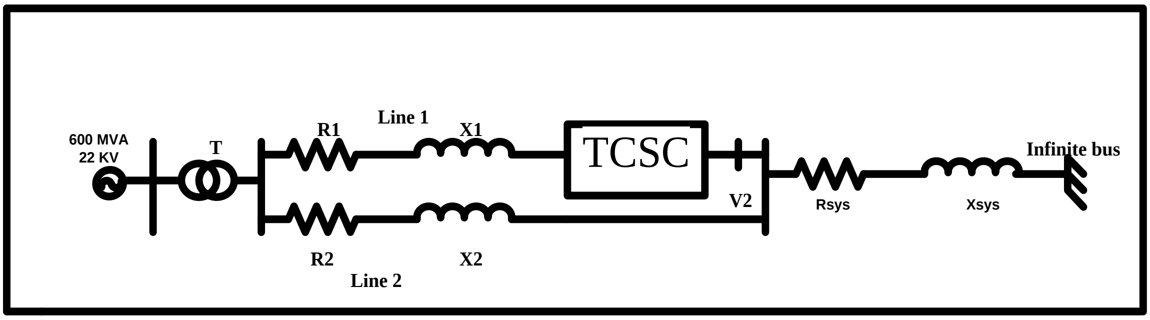

Figure.2. IEEE second bench mark model along with TCSC

III. PROPOSED CONTROLLER

A thyristor controlled damping strategy called NGH Damper for series capacitors is implemented and its results are the evinces of SSR mitigation. Succeeding research attempts established that NGH principle of damping can be extended to structure of TCSC, so that it can considerably negotiate the effect of SSR. The fundamental principle of NGH damper scheme shown in Figure.3 is to necessitate the voltage across the capacitor to zero, on condition that overreaches the fundamental component of voltage of power synchronous frequency at the end of each half-period[1].

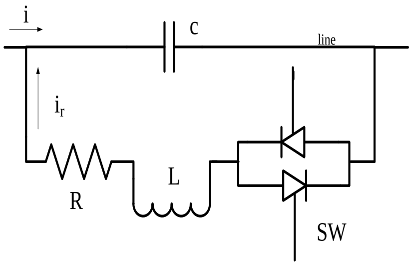

Fig.3 Basic NGH DAMPER

The basic circuit of NGH-SSR damper circuit composes of a thyristor controlled discharge resistor which is in series with a current limiter (inductor) which functions in synchronous to the power system nearer to the end of each half cycle on the capacitor voltage[1].TCSC is analogus to NGH scheme for the reason that, TCSC composes of Thyristor controlled reactor (TCR) as shown in Figure.1 and NGH damper scheme consists of a Thyristor controlled resistor and having a compensating capacitor in parallel to both of the circuits. The TCSC arrays the impedance characteristics of inductor at sub synchronous frequencies as it executes charge reversal which transmutes capacitor impedance into inductor impedance in contrast NGH circuit exhibits the resistive characteristics with definite energy dissipation for the series capacitor.The vibrations due to torsional phenomena is of highly dangerous because of exceptionally low damping in the torsional modes of rotor. The torsional damping is about 10 times lower than the damping in lateral modes. There are lot many contributions to lateral damping, whereas for torsional damping there exists only internal friction. Due to such low damping phenomena resonance effect takes its stand. There subsist many origins for torsional excitations in the rotor which relates to specific operating conditions of the rotor like flow oscillations in fluid handling machine etc..Some other excitation have their emergence in faults and transients. Numerous such faults out an existence in electrical machines such as fault synchronization in generators, short circuits, transmission line faults. In this paper the turbine –generator system is modeled by four equipments as shown in figure.4.All the torsional modes can be represented by taking rotor speed deviation. All the masses are mounted to the same shaft of rotor,so the input to the SSDC is rotor speed deviation.

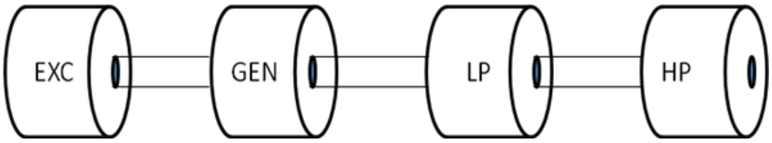

Fig.4.Modeling of the turbine–generator system

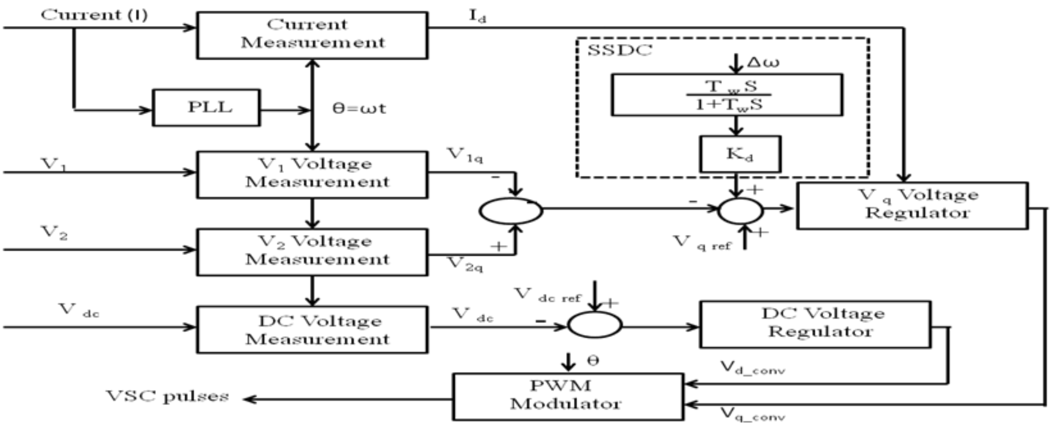

Fig.5. Block diagram of power flow control of the TCSC along with SSDC

In the above construction, there are two basic regulators used in TCSC, a Vq voltage regulator and DC voltage regulator. In the Figure.5, the input to the sub synchronous damping controller (SSDC) is chosen as the deviation in speed of the generator (Δ ω) because it contains all torsional modes. The wash out block in SSDC works as a high pass filter with Tw as time constant of wash out filter (in this paper T w=10 sec).It allows the oscillations in the input signal to pass unchanged and while it passing through it excites the derivative gain Kd .The signal that passes out from the Derivative gain manifests the existence of the sub synchronous resonance (SSR) in power system. In Figure.5Vqref depicts that the reference voltage to be injected by the steady state power flow control and is assumed to be constant.In the Figure.5 , Vd_conv and Vq_conv represents the components of voltage of converter Vq which signifies the phase and quadrature components with respect to current.Angle θ=ωt is the output of the PLL

The controller comprises of:

[1] A PLL (Phase locked loop) atunes on the positive sequence component of the current (I)as shown in Figure.5.The quadrature and direct axis components of the current and voltages are evaluated by the angle θ which is the output of the PLL. They are designated as Id,Iq and Vd,Vq as shown in figure.5.

[2] Voltages which are available before the TCSC and after the TCSC along with the output of the PLL are used for the dq0 transformation and these values are compared using a comparator.

[3] The speed deviation signal dω which contains all the torsional modes is progressed through the wash out block and it instigates the derivative gain Kd.The output of the derivative gain Kd denotes the SSR existence in the power system. The derivative effort anticipates the behavior of the system and ameliorates settling time and system stability.

[4] The outputs of the comparator which compared the dq0 transformations of voltages are compared with the output of the derivative gain Kd and is progressed towards the PI controller.

[5] The voltage across the capacitor in the TCSC is chosen and is processed to the filter and is compared with a reference value and is progressed towards the another PI controller.
[6] These output values are multiplexed and sent for dq0 to abc transformation and finally to PWM generator which generates the signal to gate of the TCSC.

IV. COA BASED TCSC

The transfer function of SSDC is

$$y = \frac{T_w s}{1 + T_w s} \Delta\omega K_d s \quad (1)$$

In order to attain satisfactory damping Kd, the derivative gain should be determined. SSDC is designed to minimize the modes of oscillation, so we can formulate the objective function as minimization of 'f' and 'f' can be written as

$$f = \int_{t=0}^{t=t_{sim}} t \,|\Delta\omega|\, dt \quad (2)$$

tsim denotes simulation time and Δω denotes the deviation in speed.The constraint in the optimization problem is the parameter of SSDC (K_d), which is bounded by

$K_{d\,min} \leq K_d \leq K_{d\,max}$ (3)

So it can be called as constrained optimization problem. Chaotic optimization algorithm based on lozi map is used to solve the optimization problem and to search for optimal value.

The flow chart of optimization problem is shown in Figure.6:

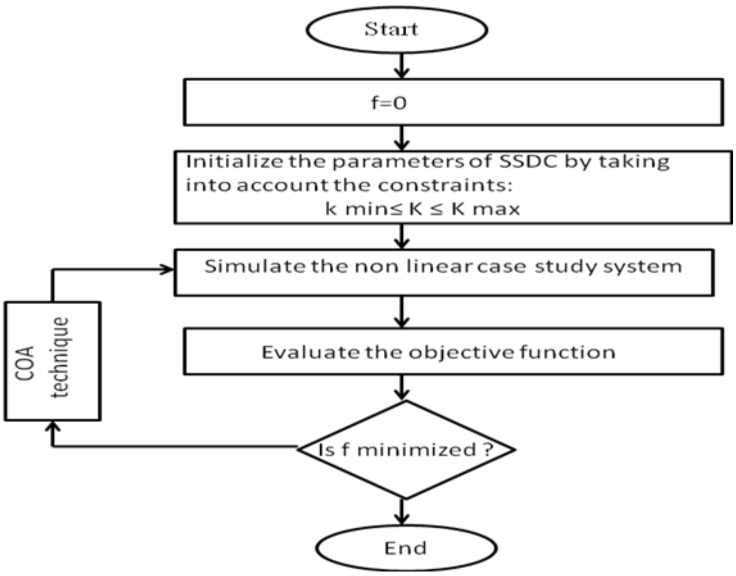

Fig.6. Optimisation flow chart

The lozi map can be formulated as [10]

$$y_1(k) = 1 - a|y_1(k-1)| + |y(k-1)| \quad (4)$$

$$y(k) = b\, y_1(k-1) \quad (5)$$

$$z(k) = \frac{y(k) - \alpha}{\beta - \alpha} \quad (6)$$

Here k denotes the iteration number. The COA is thoroughly explained in [21] .Note that COA is run for several times in order to get the optimal parameter. The parameter Kd of the SSDC is 0.839 after the COA is run for several times.

V. SIMULATION RESULTS

Consider a three phase to ground fault occurred on a transmission line. let the fault occurs at a time instant 1.0 second and it is cleared off at 2.0 sec. The magnitude of oscillations oscillations are are of low amplitude and the oscillations are mitigated at time instant 7.0 seconds.This can be observed from the Figure.7.similarly the torque of GEN-LP in p.u. can be observed form the Figure.8.one can observe from the figure though the shaft of the machine oscillated in a furious fashion, it was mitigated as soon as the fault was cleared off.From the Figure.8 we can observe that the oscillations are gradually reduced from 2.5 pu to 1 pu in mangnitude and the oscillations are permanently damped out at time instant 5.9 seconds.

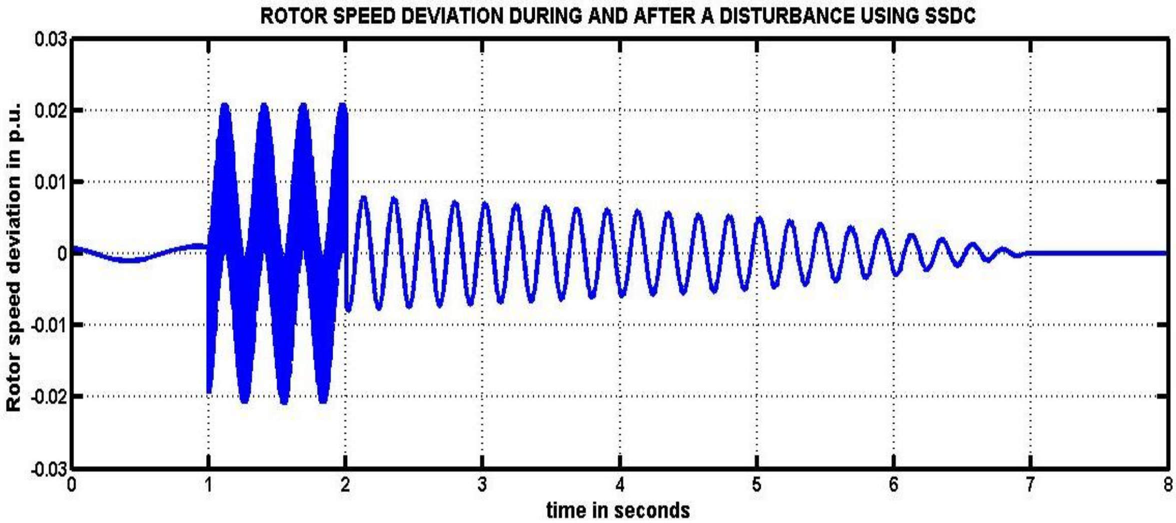

Fig.7.Rotor speed deviation during and after a disturbance using SSDC

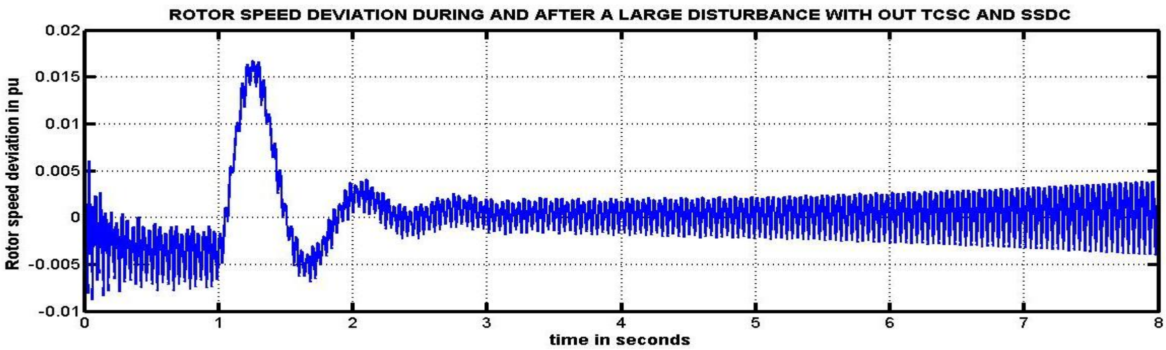

Fig.7(a).Rotor speed deviation during and after a disturbance without TCSC and SSDC

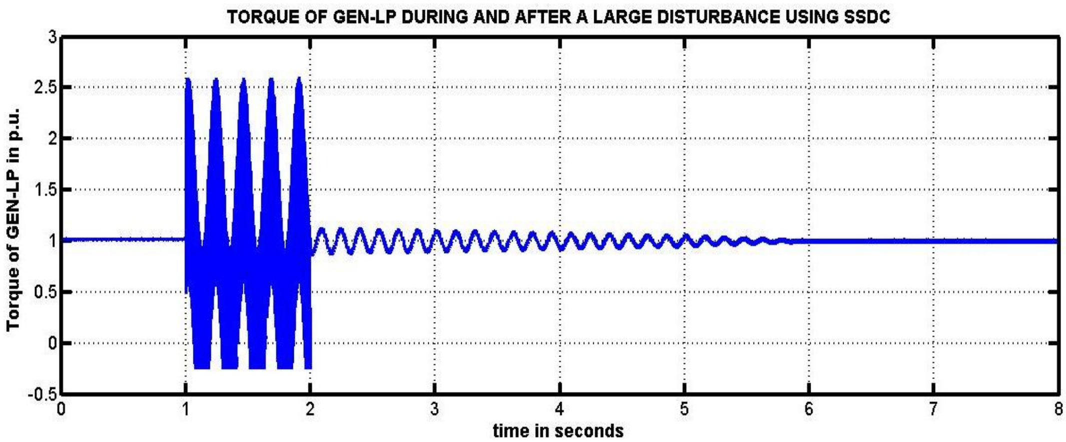

Fig.8 Torque of GEN-LP during and after a large disturbance using SSDC

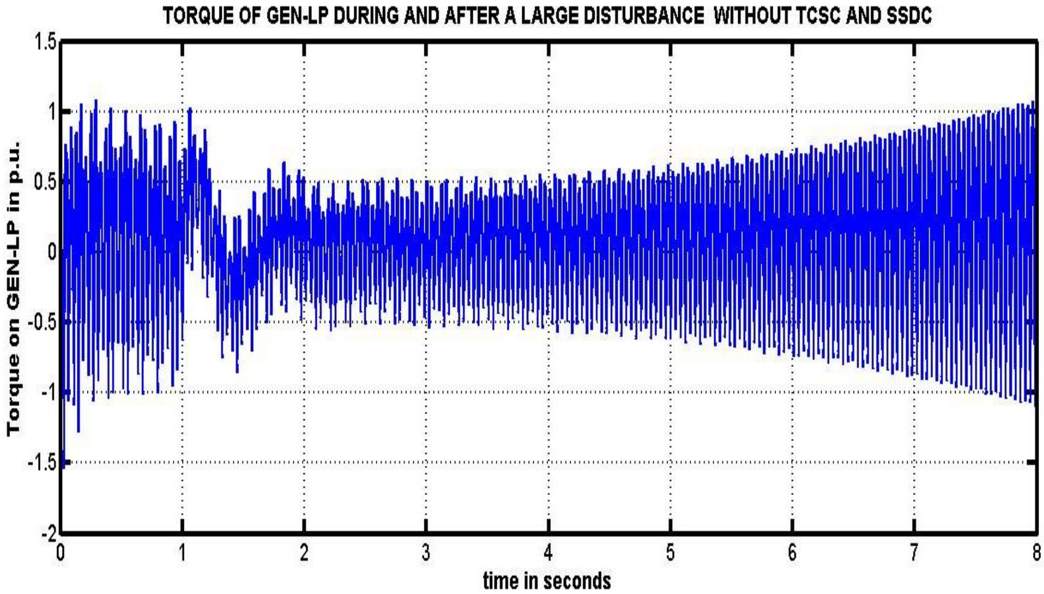

Fig.8 (a).Torque of GEN-LP during and after a large disturbance without TCSC and SSDC

VI. CONCLUSION

From the above results we found out that TCSC worked out well when a proposed controller SSDC is used along with it. The reason is choosing an input as rotor speed deviation which consists of all torsional modes to the controller. This system can be further improved by using Fuzzy logic system in the place of PI controllers or in the SSDC.

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