Transient Stability Enhancement of a Multi Machine Power System Using SVC Controller

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Abstract

Sudden change in load level affects the stability of power system. For stable operation of Power System, stability is an important concept. Stability of the system generally depends upon type of disturbance, system operating conditions. Stability can be defined as the ability of system to maintain synchronism or to retain some steady state value after occurrence of fault in the system. A system is said to be synchronously stable (i.e., retain synchronism) for a given fault if the system variables settle down to some steady-state values with time, after the fault is removed. For the improvement of transient stability FACTS devices are used to damp out system oscillation. This paper presents the model of a SVC (Static VAR Compensator) which is controlled externally by an Auxiliary Controller for damping power system oscillations. Different auxiliary controller structures have been designed & controller's parameters have been optimized by using Ziegler-Nichols close loop tuning method. Simulation has been carried out with & without SVC Auxiliary Controllers under three phase fault contingencies. Comparison has been carried out without, with SVC & with SVC Auxiliary controllers.

Keywords: SVC, Transient Stability, Auxiliary Controller, Ziegler Nichols, FACTS.

1. INTRODUCTION

Power system comprises of generation, transmission and distribution system. It is the largest man made system. Transmission system is used to transmit power from generating station to load centers. In case of change in loading in transmission line, stability of the system is a major concern. The problem of stability can be solved by use of various types of available FACTS controllers [1]. The aim of this paper is to investigate the influence of SVC on improving transient stability of multi machine power system. In multi machine system, all the machines maintain synchronism, but when fault occur on any bus then it will result in the oscillations. These oscillations are damped out fast with the help of SVC and auxiliary SVC controller thereby enhances the transient stability. The proposed model is designed in Simpower system using MATLAB.

In the paper, Section I describes introduction. Section II describes about SVC controller. Section III explains the brief description of the test system taken whereas various proposed approaches have been explained in section IV. Section V illustrates the simulation results of the system and finally section VI concludes.

2. SVC DESCRIPTION

An SVC is a controlled shunt suceptance which injects or absorbs reactive power into the system [2] thereby mitigate the power system oscilations and improve the transient stability of the system. Its can also used to improve the steady stade stability and voltage stability.

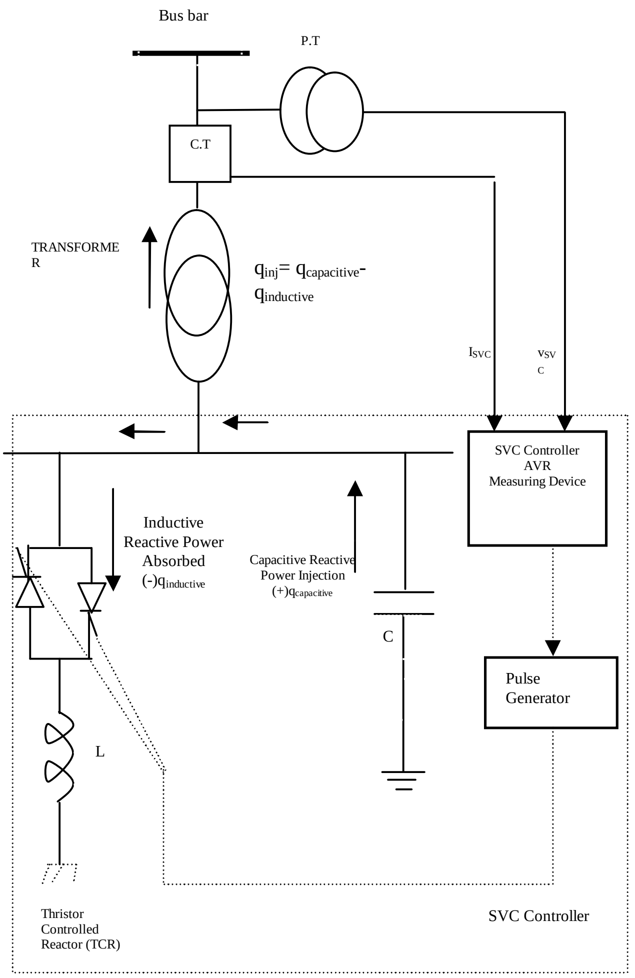

Fig. 1 Basic Diagram of SVC Control

3.POWER SYSTEM UNDER STUDY

The system consists of two generators (G1 and G2) divided into two subsystem and are connected via tie line as shown in figure 2. G1 is 1000 MW hydraulic generation plant, connected to a load center through a long 500 kV, 700 km transmission line through transformer. Generator G2 is 5000 MW hydraulic plant located close to load center of 5000MW resistive load. Generators G1 and G2 are equipped with a Hydraulic Turbine and Governor (HTG), Excitation system and Power System Stabilizer (PSS). SVC of 200 MVar is connected at the center of transmission line. The value of various parameter used are given in Appendix-A.

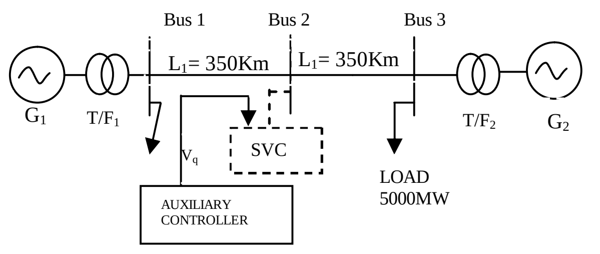

Fig 2: Two Machine Model with SVC auxiliary Controller

4.THE PROPOSED APPROACHES

To enhance power system stability and to reduce the damping time. Different types of Auxiliary controllers are discussed by many researchers [3]-[7] to enhance the power system stability. Paper [3] describes about PID based SVC auxiliary controller to enhance voltage stability of the system, while paper [5], presents the model of PI and PD based SVC auxiliary controller with washout and lead lag compensator for the improvement of voltage stability. Paper [7] designed the structure of lead lag auxiliary controller along with PID based damping controller whose parameter are optimized using GA for the enhancement of voltage stability.

In the following section different type of SVC Auxiliary controllers have been designed for the enhancement of Transient stability and the controller parameters are tuned by Ziegler-Nichols, a correction technique.

4.1PID based Auxiliary Controller

An auxiliary signal from PID controller enhances the stability and damp out the oscillations quickly as compared to SVC without auxiliary signal.

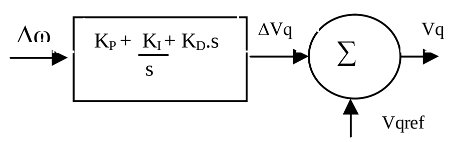

Fig 3: PID based Damping Controller

4.2Control of SVC with washout and with 2 stages of lead-lag compensator

Another structure of auxiliary controller of SVC is shown in fig 4. A gain block having gain K_1, a washout block and two stages of phase compensation block combines to form the proposed type of auxiliary controller. Washout block, with the time constant T_w, serves as high pass filter, which can allow signal to pass unchanged. The lead lag compensation blocks (time constant T_{1a}, T_{2a} and T_{3a}, T_{4a}) provide the best phase lead characteristics to compensate the phase lag between input and output signals. V_{qref} is the reference injected voltage as desired by the steady state power flow control loop. During large disturbance transient period V_{qref} is assumed to be constant. The desired value of compensation is summation of change in the SVC injected voltage ΔV_q and V_{qref}. With the use of washout and 2 stages of lead-lag compensator enhances the stability and damps the oscillations quickly as compared to above case.

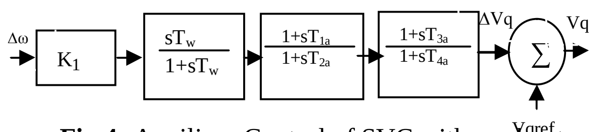

Fig 4: Auxiliary Control of SVC with washout and lead lag compensator

4.3 PD based Auxiliary Controller with Washout and Lead Lag compensators

Power Oscillation Damping unit is designed using PD control in addition to washout and lead-lag compensator. This controller structure further enhances the transient stability.

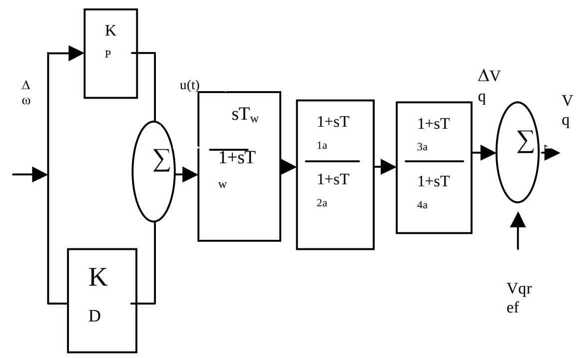

Fig 5: PD based SVC auxiliary Controller

4.4 PI based Auxiliary Controller with Washout and Lead Lag compensators

An addition of PI controller to washout and lead-lag compensator further enhances the oscillations in the system by reducing the damping period.

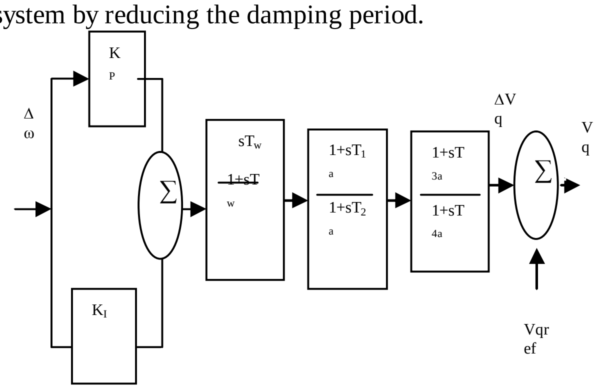

Fig 6: PI based SVC Auxiliary Controller

4.5 Series PID Controller with Washout and Lead Lag compensators

Auxiliary signal to SVC controller achieved by connecting PID controller in series with washout and lead lag compensator to damp out the Power system oscillations.

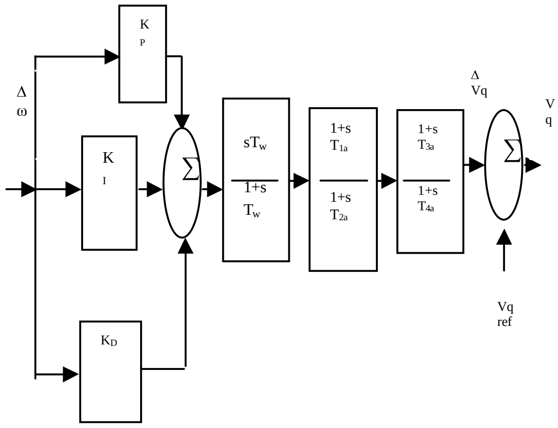

Fig 7: Series PID SVC Auxiliary Controller with washout and lead lag compensator

4.6 Parallel PID Controller with Washout and Lead Lag Compensator

Auxiliary control signal to SVC Controller is obtained by using PID controller in parallel to washout and lead-lag compensator.

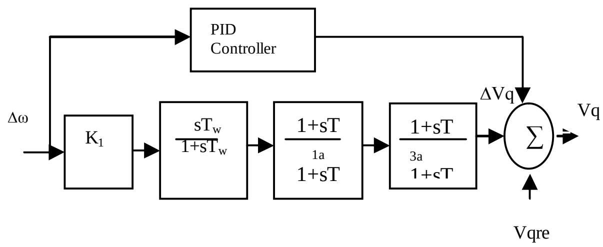

Fig 8: Parallel PID SVC Auxiliary Controller with washout and lead lag compensator

5.SIMULATION

Trasient stability analysis is being carried out with different control schemes discussed in section IV. The three phase fault is created at bus no 1 for 50msec. The parameters of various proposed controllers are given in Appendix –B. The simulation result are given in fig 9(i) to fig 9(viii).

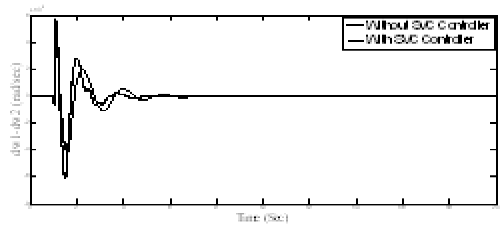

Figure 9(i): Time response of speed deviation (with and without SVC)

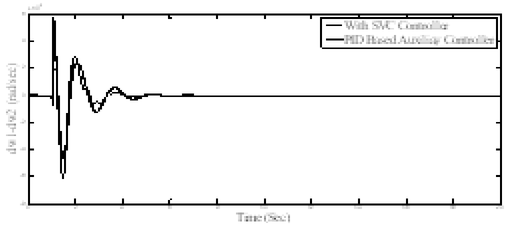

Figure 9(ii): Time response of speed deviation (with SVC controller and PID Based Auxiliary Controller)

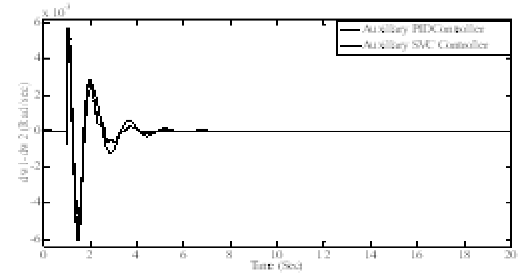

figure 9(iii): Time response of speed deviation (with SVC Auxiliary Controller with washout, lead lag compensator and PID based SVC auxiliary controller)

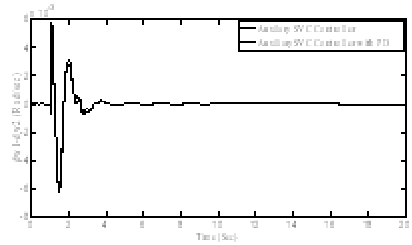

Figure 9(iv): Time response of speed deviation (with SVC Auxiliary Controller with washout, lead lag compensator and PD in series with washout and lead lag compensators)

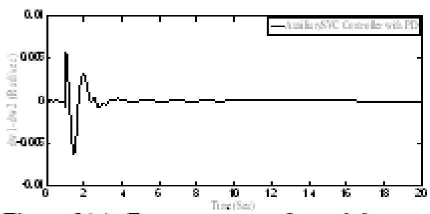

Figure 9(v): Time response of speed deviation (SVC Auxiliary Controller with PD in series with washout and lead lag compensators)

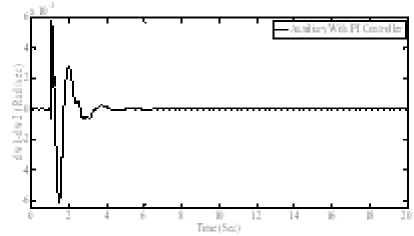

Figure 9(vi): Time response of speed deviation (SVC Auxiliary Controller with PI in series with washout and lead lag compensators)

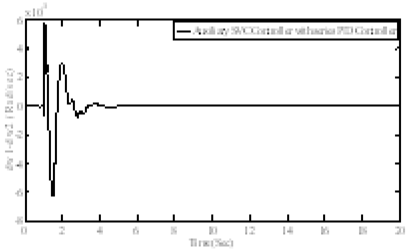

Figure 9(vii): Time response of speed deviation (with SVC Auxiliary Controller with PID in series with washout and lead lag compensators)

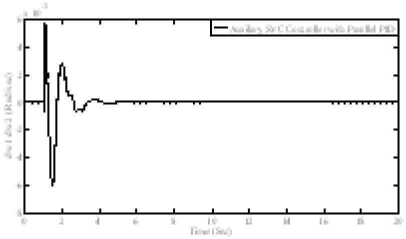

Figure 9(viii): Time response of speed deviation (SVC Auxiliary Controller with PID in parallel with washout and lead lag compensators)

6.CONCLUSION

This paper presents the transient stability enhancement of multi machine system in order to reduce the settling time by the use of auxiliary controller of SVC under three phase fault condition. The use of such auxiliary efficient controller made the system reliable and cheap. Advantages of such controllers are that only a small controller can handle a robust interconnected power system efficiently and effectively. For stability improvements, if an externally (PI, PD, PID) controlled auxiliary controller with washout and phase lead lag compensator is connected to SVC controllers in the network, then a small rating SVC can damp out oscillation affecting the system becomes stable in faster way. The simulation results reveal that without the use of SVC settling time is around 8.5sec. But when SVC controller is used in the center of the network settling period reduced to 7.8 sec. But the use of external control to SVC with PID controller in place of washout and lead lag compensators further reduces the stability time to 7 sec. On the application of external control to SVC with washout and 2 stages of lead lag compensation further reduces the oscillations and enhances the stability period to 5.9sec. While the use of SVC Auxiliary control with PD reduces the setting time to 5.6 sec which is further reduces to 5.4 seconds by the use of auxiliary SVC controller with PI controller. While the use of series and parallel SVC Controller discussed in proposed structure in subsection 5 and 6 are comparable having stability period of almost 5 seconds.

Appendix-A

Generator 1, M1:

S_B = 1000 MVA, H =3.7 s, V_B = 13.8 kV, f = 60 Hz, R_S =2.8544 e -3, X_d =1.305, X_d'= 0.296, X_d ''= 0.252, X_q = 0.474, X_q ' = 0.243, X_q''= 0.18,
T_d = 1.01 s, T_d' = 0.053 s, T_{qo}''= 0.1 s, Pe=0.95 pu.

Generator 2, M2:

S_B = 5000 MVA, H =3.7 s, V_B = 13.8 kV, f = 60 Hz, R_S =2.8544 e -3, X_d =1.305, X_d'= 0.296, X_d''= 0.252, X_q = 0.474, X_q ' = 0.243, X_q''= 0.18,
T_d = 1.01s, T_d' = 0.053s, T_{qo}''= 0.1 s, P_e=0.809094pu.
Load at Bus3: 5000MW

Transformer 1:

1000 MVA, 13.8/500 kV, 60 Hz,
R_1 =R_2= 0.002, L_1 = 0, L_2=0.12, D_1/Y_g connection,
R_m = 500, L_m = 500

Transformer 2:

1400 MVA, 13.8/500 kV, 60 Hz,
R_1 =R_2= 0.002, L_1 = 0, L_2=0.12, D_1/Y_g connection,
R_m = 500, L_m = 500

Transmission lines:

3-Ph, 60 Hz, Length (L_1) = 350km
R_1 = .01755 Ω/ km, R_0= 0.2758 Ω / km, L_1= 0.8737e-3 H/km, L_0 = 3.220e-3 H/ km, C_1 = 13.33e-9 F/ km, C_0 = 9.297e-9 F/ km

Hydraulic turbine and governor:

K_a = 3.33, T_a = 0.07, G_{min} = 0.01, G_{max} =0.97518, V_{gmin} = -0.1 pu/s, V_{gmax} = 0.1 pu/s, R_p = 0.05, K_p = 1.163, K_i = 0.105, K_d = 0, T_d = 0.01 s, β =0, T_w = 2.67 s each

Excitation system:

T_r = 0.02 s, K_a =200, T_a = 0.001 s, K_e =1, T_e =0, T_b = 0, T_c =0, K_f = 0.001, T_f = 0.1 s,
E_{fmin} = 0, E_{fmax} = 7, K_p = 0 each

Static Var Compensator:

500KV, ±200 MVAR

APPENDIX – B

Washout time constant T_W=10sec
Lead Lag Compensator Constants:
T_{1a}=0.90sec T_{2a}=0.0207sec
T_{3a}=0.95 sec T_{4a}=0.2207sec

S. No	Controller	Parameters Values
1	Auxiliary Control of SVC with washout and with 2 stages of lead-lag compensator	K_s=-1.77
2	PID Based Auxiliary Controller	K_P=-1.7, K_I=0.55, K_D=0.01
3	PD based Auxiliary Controller with Washout and Lead Lag compensators	K_p=-1.7, K_D=0.01
4	PI based Auxiliary Controller with Washout and Lead Lag compensators	K_p=-1.7, K_I=0.55
5	Series PID Controller with Washout and Lead-Lag -compensators	K_p=-1.5, K_I=1.27, K_D=0.0590
6	Parallel PID Control with Washout and Lead Lag compensator	K_p=-2.5, K_I=2.54, K_D=0.0690 K_s=-1.79

ACKNOWLEDGEMENTS

The first author acknowledges with gratitude in terms of technical support offered by YMCA University of Science and Technology, Faridabad, India.
The second author is the student of YMCA University of Science and Technology, Faridabad, India.

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