Voltage Level Improvement of Power System By Using SVC With POD Controller

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Abstract

This paper presents the effects of Static VAR Compensator (SVC) which is controlled externally by a POD controller for voltage stability improvements of a on line power system. The new designed P.O.D controller is very efficient for voltage stability under transient conditions. This paper discusses and demonstrates how SVC with P.O.D controller has successfully been applied to power system for effectively regulating system voltage for different types of faulted condition. One of the major reasons for installing a SVC is to improve dynamic voltage control and thus increase system load ability during transient condition. This paper presents modeling and simulation of SVC & P.O.D controller in MATLAB/Simulink. In this paper, Two types of power system network having same voltage rating has been considered for simulation & compared the performance of SVC with POD controller for both network. This work is presented to improve the transmission line voltage stability & machine oscillation damping stability by using SVC without & with POD controller & compared their performance to enhance the stability of a power system. Simulation results shows that SVC with POD controller is more effective to enhance the voltage stability and increase transmission capacity in a power system.

Keyword

Static VAR compensator (SVC),TSR, TCR ,AVR, Voltage regulation, MATLAB Simulink, P.L.L & P.O.D controller.

Introduction

Power system stability improvements is very important for large scale system. The AC power transmission system has diverse limits, classified as static limits and dynamic limits[1 3].Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to enhance same types of stability augmentation[1]. For many reasons desired performance was being unable to achieve effectively. A static VAR compensator (SVC) is an electrical device for providing fast-acting reactive power compensation on high voltage transmission networks and it can contribute to improve the voltages profile in the transient state and therefore, it can improve the quality performances of the electric services[3]. A SVC can be controlled externally by using properly designed different types of controllers which can improve voltage stability of a large scale power system. Authors also designed P.I controller[5] & now more efficient P.O.D controller has been designed for SVC to injects V_{qref} externally. The dynamic nature of the SVC lies in the use of thyristor devices (e.g. GTO, IGCT)[4]. Therefore, This paper presents thyristor based SVC with POD controllers to improve the performance of multi-machine power system.

CONTROL CONCEPT OF SVC

An SVC is a controlled shunt susceptance (B) which inject reactive power (Q_{net}) into thereby increasing the bus voltage back to its net desired voltage level. If bus voltage increases, the SVC will inject less (or TCR will absorb more) reactive power, and the result will be to achieve the desired bus voltage. Fig.1 & Fig.2, represents SVC based control system with AVR, P.L.L & POD controller.

1. Control concept of AVR controller

SVC (AVR) controller always monitor the bus voltage(V_{svc}) & current (I_{svc}), it compare the actual bus voltage with V_{ref} & taking error voltage, $V_{error} = V_{ref} – V_a – (I_{svc}*X_{sl})$ & integrate it in limit ($-Q_{cap}$ to $+Q_{ind}$), the net susceptance has been produced which control the pulse generator & Thus TCR & TSC are controlled & voltage becomes stable towards it's V_{ref} shown in fig.1 [5-6].

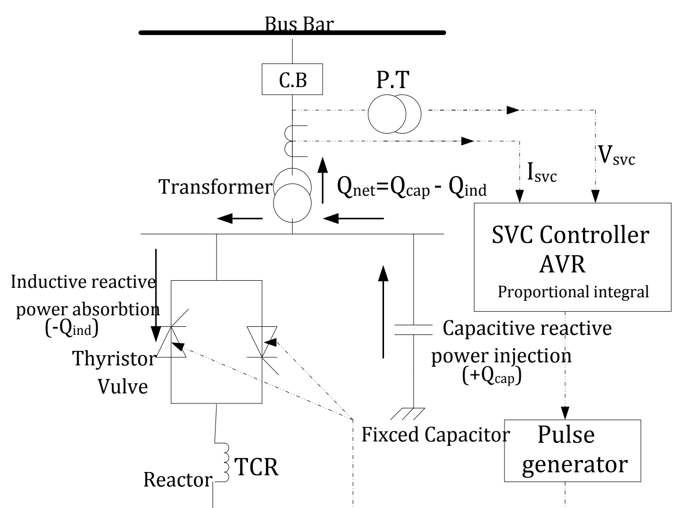

Fig. 1 SVC based control system(AVR)

2. Control concept of P.L.L controller

The control system consists of,

(a). A measurement system measuring the positive-sequence voltage to be controlled. A Fourier-based measurement system using a one-cycle running average is used.

(b). A voltage regulator that uses the voltage error (difference between the measured voltage V_m and the reference voltage Vref) to determine the SVC susceptance B needed to keep the system voltage constant.

(c). A distribution unit that determines the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of TCRs.

(d). A synchronizing system using a phase-locked loop (PLL) synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the thyristors. This is shown in Fig. 2 [4].

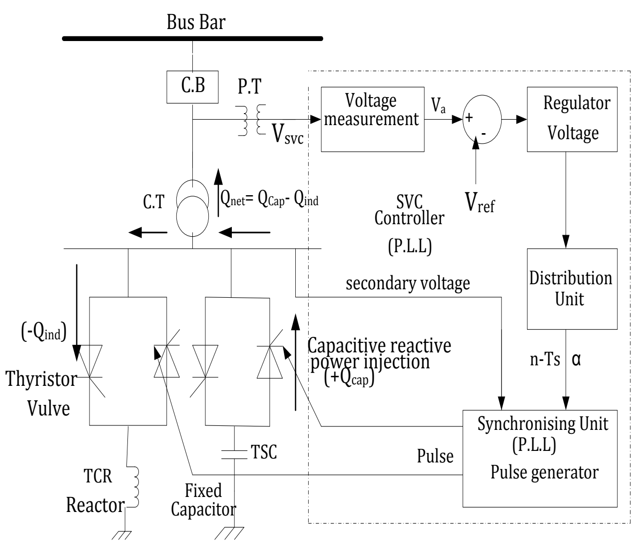

Fig.2 SVC based control system with P.L.L controller

3. SVC V-I Characteristic

The SVC can be operated in two different modes:

a). In voltage regulation mode (the voltage is regulated within limits as explained below).

b). In VAR control mode (the SVC susceptance is kept constant).

From V-I curve of SVC, From Fig.3,

$V=V_{ref}+X_s.I$,: In regulation range($-Bc_{max}<B<Bc_{max}$)

$V=I/Bc_{max}$, : SVC is fully Capacitive($B=Bc_{max}$)

$V=1/Bl_{max}$, : SVC is fully inductive($B=Bl_{max}$)

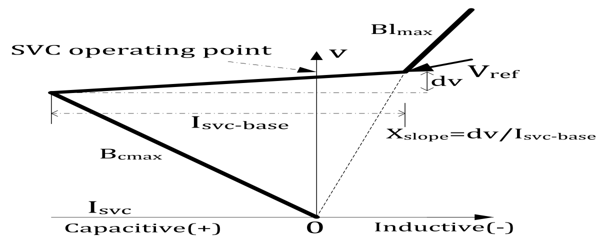

Fig.3 Steady state(V-I) characteristic of a SVC

Network modeling with SVC

This example described in this section illustrates modeling of a simple transmission system containing two hydraulic power plants. Static VAR compensator (SVC) have been used to improve voltage stability and power system oscillations damping. A single line diagram represents a simple 500 kV transmission system is shown in Fig. 4.

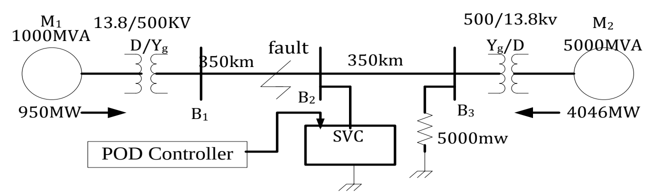

Fig.4 Single line diagram of 2-machine power system

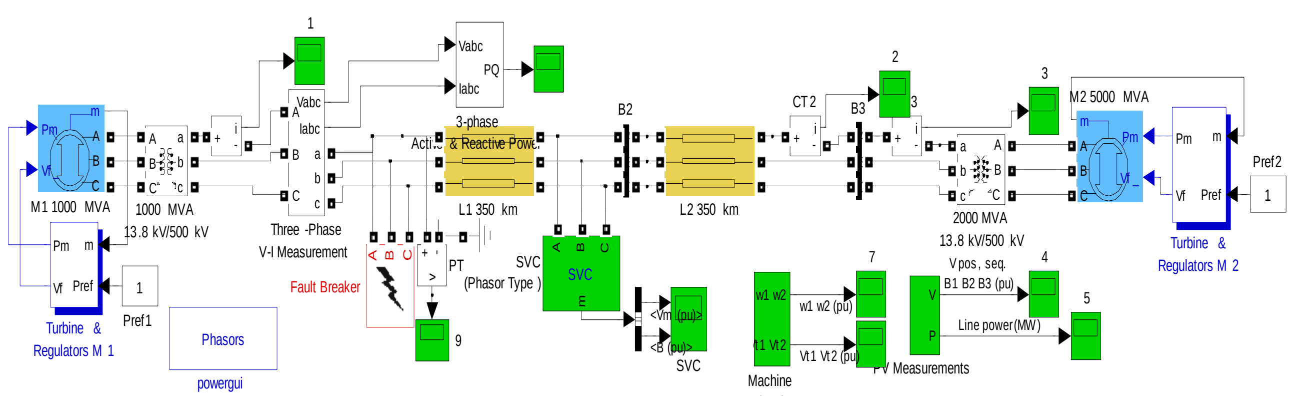

Fig.5 SVC simulink Model of a 2-machine power system

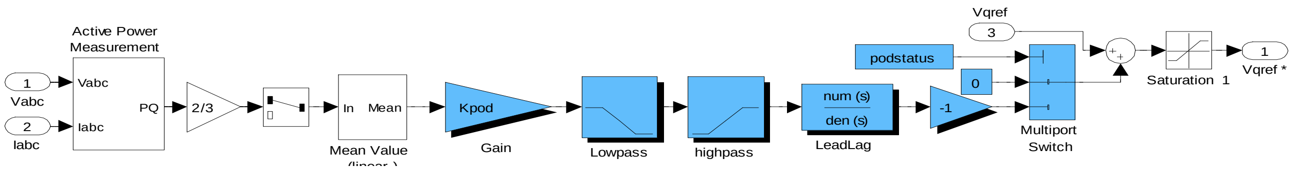

Fig.6 Simulink model of P.O.D Controller

A 1000 MW hydraulic generation plant (M1) is connected to a load centre through a long 500 kV, 700km transmission line. A 5000 MW of resistive load is modeled as the load centre. The remote 5000 MVA plant and a local generation of 5000 MVA (plant M2) feed the load. A load flow has been performed on this system. To maintain system stability after faults, the transmission line is shunt compensated at its centre by a 200 MVA capacitive & 200MVA inductive Static VAR Compensator (SVC). The two machines are equipped with a hydraulic turbine and governor (HTG), excitation system, and power. Any disturbances that occur in power systems due to single line faults or 3-phase faults can result in inducing electromechanical oscillations of the electrical generators.

Such oscillating swings must be effectively damped to maintain the system stability and reduce the risk of outage. To ensure robust damping SVC has been controller externally by properly deigned POD controller. The complete simulink model of this network is shown in fig.5 & block diagram of POD controller is shown in fig.6

1. Simulation Results(Without POD)

The load flow solution of the above system is calculated and the simulation results are shown below. Two types of faults: 1.1 Single phase fault & 1.2 L-L fault have been considered.

1.1 Single phase fault

Let us consider that the fault was occurred at 0.1s & circuit breaker was opened at 0.2s (3-phase 4-cycle fault),Without SVC, the system voltage & machines oscillates goes on unstable[Fig.6(a-b)]. But if SVC(without POD) is applied then voltage becomes stable within 3s [Fig.6(c)] & machines oscillation becomes stable within 3s [Fig.6(d)] & whole result has been summarized in table-I.

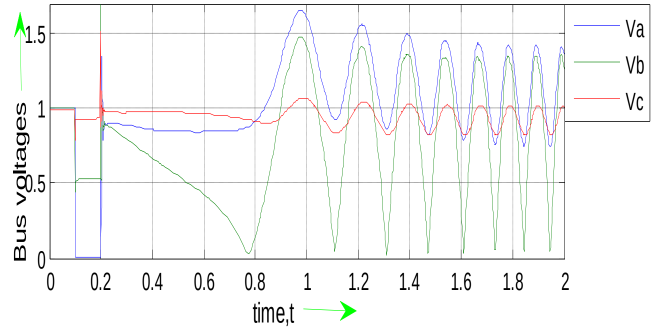

Fig. 6(a) Bus voltages in p.u for 1-phase fault(without SVC)

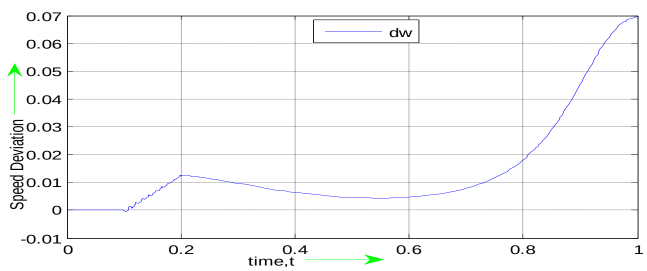

Fig.6(b) Speed deviation for 1- phase fault(without SVC)

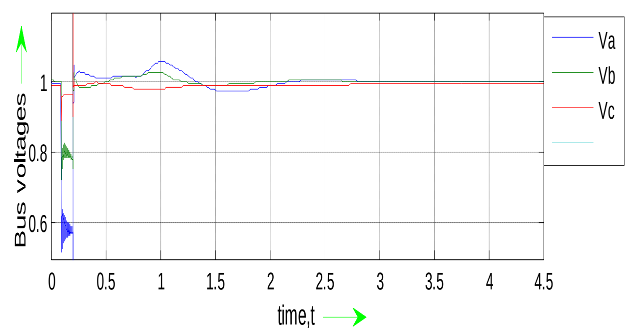

Fig.6(c) Bus Voltages in p.u for 1-phase fault (with SVC)

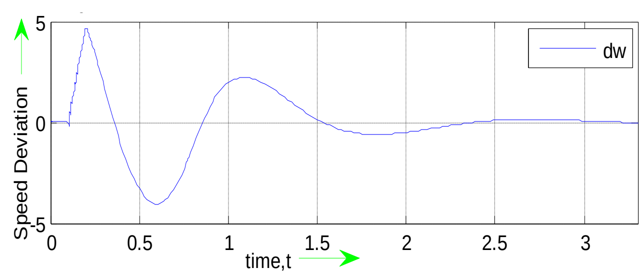

Fig.6(d) Speed oscillations for 1- phase fault(with SVC)

1.2 Line-Line fault

During 3-phase faults, If no SVC is applied then system voltage & machines speed deviations becomes unstable But when SVC(without POD) is applied then the system voltage becomes stable within 5s [Fig.6(e)] & machines speed deviation becomes stable within 5s [Fig.6(f)].

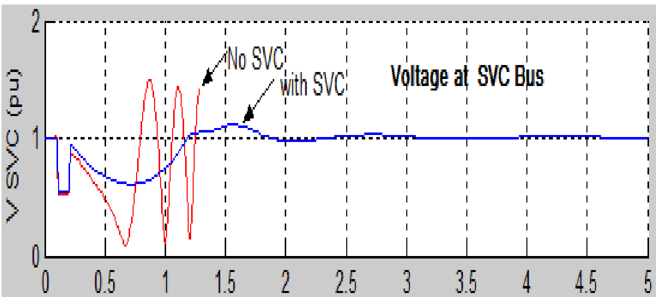

Fig.6(e) Bus Voltage(Va) in p.u for 1-phase fault (with SVC)

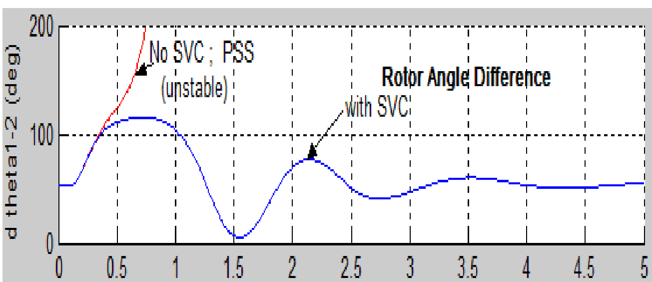

Fig.6(f) Machines speed deviation for L-L fault

Network modeling of SVC with POD

Power Oscillation Damping (POD) is a controller which externally injects V_{qref} to the SVC. The POD controller consists of active power measurement system, a general gain, a low-pass filter, washout high-pass filter, a lead compensator, and an output limiter[Fig.6]. The network remains same as like as Fig.5, only SVC is controlled extarnally by P.O.D controller. All values of the POD controller has been taken from ref.[6].

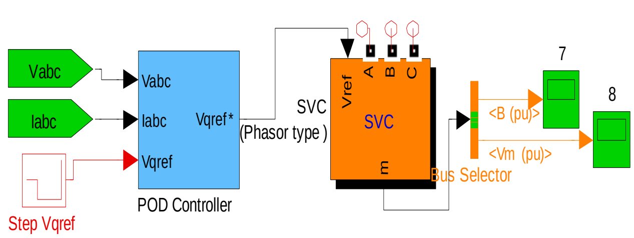

Fig.7 Simulink model of SVC with POD controller

1. Simulation Result (SVC with P.O.D)

Two types of faults has been considered: 5.1.1 Single phase fault & 5.1.2 L-L faults.

1.1 Single phase fault

During 1-phase faults, if POD is used as SVC controller then, the system voltage becomes stable within 2.5s with 0% damping [Fig.7(a)] & Machines speed deviation becomes stable within 2s [Fig.7(b)].

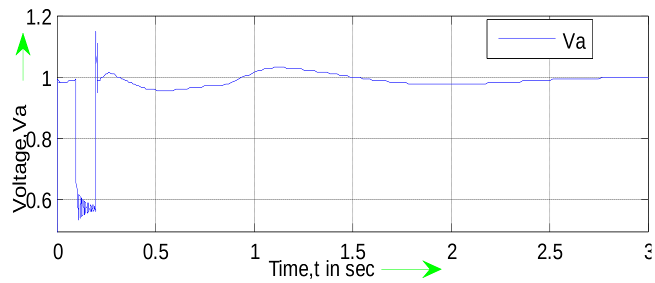

Fig. 7(a) Bus voltage(B_1) in p.u. for 1-phase fault

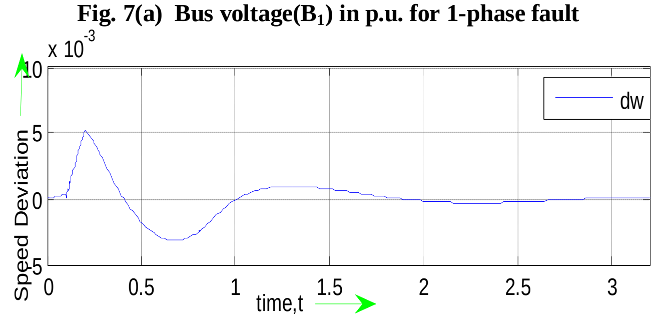

Fig.7(b) Machines speed oscillations for 1- phase fault

1.2. Line-Line fault

During L-L faults, Although initial damping was higher then 1-phase fault, If POD is used as SVC controller then the system voltage becomes stable within 3.5s with 0% damping [Fig.7(c)] & Machines speed deviation becomes stable within 3.5s with 0.01% damping [Fig.7(d)].

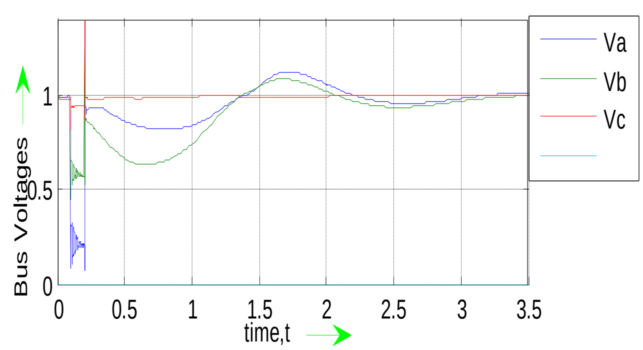

Fig.7(c) Bus voltage(B_1 B_2 B_3) in p.u. for L-L faults.

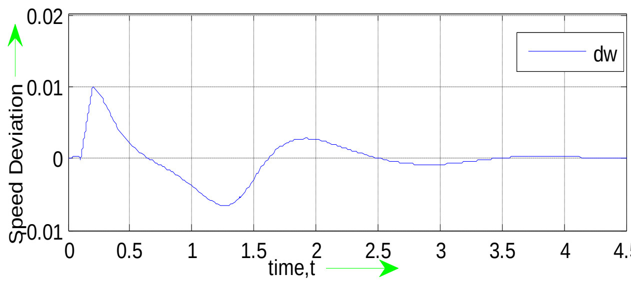

Fig.7(d) Machines speed oscillations for L-L faults

Another network with SVC (POD)

This is an another illustrated the power system model of SVC with P.O.D controller. The SVC is rated +30 Mvar capacitive and -30 Mvar inductive. The two 500kv Three-Phase Programmable Voltage Source is used to vary the system voltage to observe the SVC performance. The SVC is set in voltage regulation mode with a reference voltage V_{ref}=1.0 pu. The voltage droop is 0.03 pu/ 100MVA, so that the voltage varies from 0.97 pu to 1.015 pu when the SVC current goes from fully capacitive to fully inductive. Initially the source is generating nominal voltage. Then, voltage is successively decreased (0.97 pu at t = 0.1 s), increased (1.03 pu at t = 0.4 s) and finally returned to nominal voltage (1 pu at t = 0.7 s).

A positive of Q(pu) value indicates inductive operation and a negative value of Q(pu) value indicates capacitive operation. A positive value of SVC susceptance indicates that the SVC is capacitive and a negative value indicates inductive operation. The SVC response speed depends on the voltage regulator integral gain Ki (Proportional gain K_p is set to zero), system strength (reactance X_n) and droop (reactance X_s). If the voltage measurement time constant and average time delays T_d due to valve firing are neglected, the system can be approximated by a first order system having a closed loop time constant.

$$Tc= 1/(Ki\ (X_n+X_s))$$ [6]

With system parameters

$$Ki = 400$$

$$X_n = 0.0667 \text{ pu/100 MVA}$$

$$X_s = 0.03 \text{ pu/100 MVA}$$

In the present work system is simulated in simulink to observe the positive sequence voltage profile by using SVC with & without POD. These Simulation curves are result of this paper. Initially the source is generating nominal voltage. Then, voltage is successively decreased (0.97 pu at t = 0.1 s), increased (1.03 pu at t = 0.4 s) and finally returned to nominal voltage (1 pu at t = 0.7 s) through 500KV Three Phase Programmable Voltage Source. Waveforms of Q(pu), V_m(pu) and B(pu) are shown in Fig.8

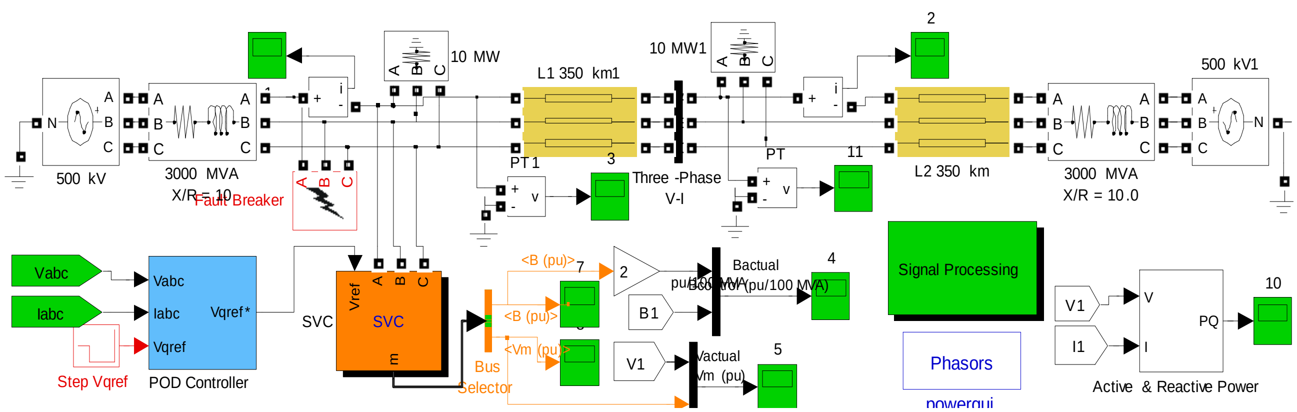

Fig.8 Another Complete simulink model of SVC with P.O.D controller

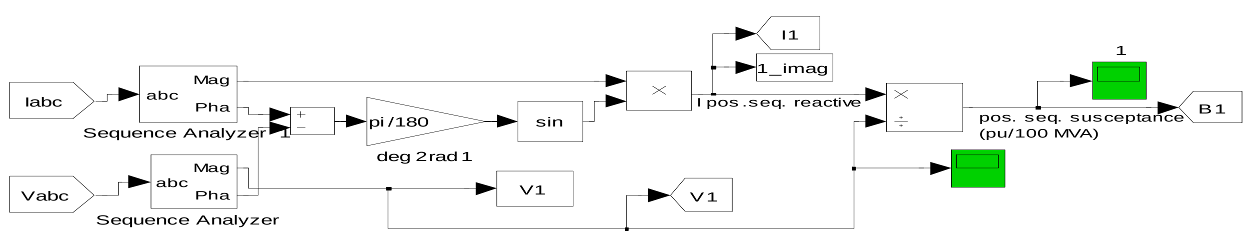

Fig.9 Simulink diagram of Signal Processing unit

1.Simulation Results

The load flow solution of the above system is calculated and the simulation results are shown below. Two types of faults: 1.1 Single phase fault & 1.2 three phase fault have been considered.

1.1 Single-phase fault

During 1-phase fault, when fault occurred at 0.1s,then Bus voltage become fall down[Fig.9(a)] & SVC injects +Q to the line. Although the fault is cleared at 0.2s (3-phase 4-cycle fault),As the bus voltage is lower then reference, so SVC injects +Q upto 0.4s[Fig.9(b)].The voltage becomes increasing at 0.4s then SVC injects –Q to the line & finally the system voltage becomes stable at 0.72s.

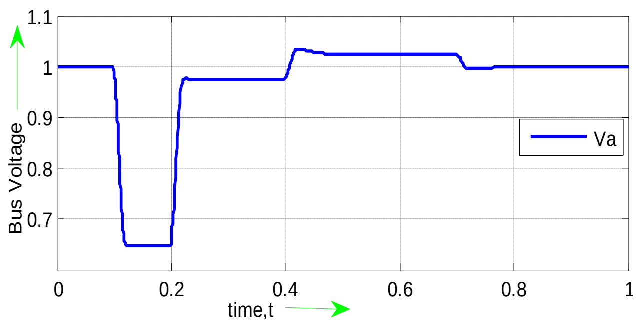

Fig. 9(a) Voltage(Va) in p.u (with POD)

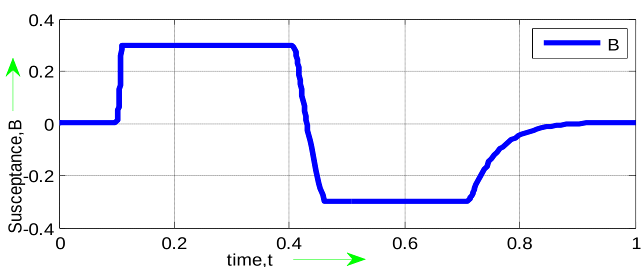

Fig. 9(b) Susceptance in p.u (with POD)

1.2 Three phase fault

During 3-phase fault, the system voltage becomes stable as like as described in section 6.1.1.Although the damping is greater for 3-phase faults, POD is such an efficient controller that again the system voltage become stable at 0.72s shown in fig.9(c-d-e) .

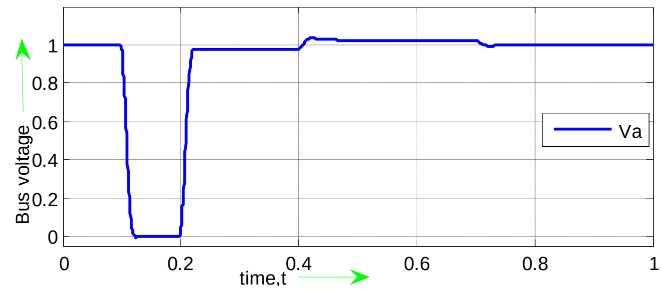

Fig.9(c) Voltage(Va) in p.u (with POD)

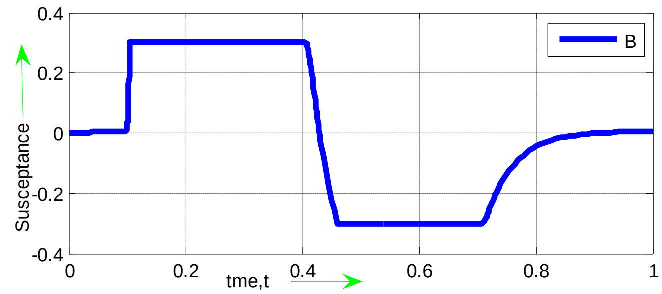

Fig.9(d)Susceptance in p.u (with POD)

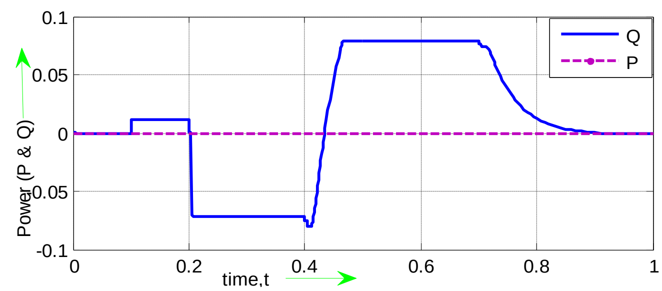

Fig.9(e) Bus power for 3-phase faults(SVC with POD)

Results & Discussions

In this paper, Two same 500KV transmission line has been simulated in two ways: (a) 2-machine model of SVC with P.O.D controller[Table-I] (b)Two programmable voltage source of SVC with P.O.D controller[Table-II].

Table-I, Performance comparison of network [Fig.5] of SVC without & with P.O.D Controller.

		1-Ø fault (Stable time)		3-Øfault (Stable time)		
SVC Controller	SVC Rating	volt	dω	volt	dω	damping
without	200MVA	3s	3s	5s	5s	0.5%
P.O.D	50MVA	1.5s	2s	3.2s	2.5s	0.01%

Table -II, Performance analysis of network [Fig.8] of SVC with P.O.D Controller.

		1-Ø fault (Stability time)		3-Øfault (Stability time)	
SVC Controller	SVC Rating	volt	damping	volt	damping
P.O.D	30MVA	0.72s	2%	0.72s	0.5%

Conclusion

The actual positive sequence voltage level has been improved in a power system model of SVC with or without POD controller for different types of faulted conditions. Although authors designed another controller (P.I) for SVC[5], POD is also an very efficient controller for SVC. From above results, the proposed POD controller may be highly suitable as SVC controller because of Shorter voltage stability time & machine oscillation becomes damped out within very shortest possible time. Rather that, If POD controller is used then only small rating of SVC becomes enough for stabilization of robust power system within very shortest possible time for both steady state & dynamic conditions.
For Other FACTS devices namely SSSC, STATCOM, UPFC controllers may be designed for both transient and steady state stability improvement of a power system by using POD controller.

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