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Improvement of Power System Stability by using SVC with Cascade PID Controller

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Improvement of Power System Stability by using SVC with Cascade PID Controller

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Keywords: SVC, voltage regulator, cascade propotional integral differential controller, matlab simulink.

I. INTRODUCTION

The challenge facing power system engineers today is to use the existing transmission facilities to greater effect[1]. Power system should retain its synchronism during and after all these kind of disturbances. Therefore the transient stability is an important security in power system design. So FACTS has come to help the power system engineer [2-3]. The SVC is one of the important FACTS devices whose effectiveness for voltage control is well known. The AC power transmission system has diverse limits, classified as static limits and dynamic limits[4-5].Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to enhance same types of stability augmentation[6]. For many reasons desired perfor-mance 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 voltage profiles in the transient state and therefore, it can improve the qualities and performances of the electric services[6]. An SVC can be controlled externally by using properly designed different types of controllers which can improve voltage stability of a large scale power system[7]. However, in this study, With a view to get better performance, A new PID has been designed & proposed for SVC to injects V_{qref} externally for the improvement of power system stability. The dynamic nature of the SVC lies in the use of thyristor devices (e.g. GTO, IGCT)[6]. Therefore, thyristor based SVC with PID controllers has been used to improve the performance of 2-machine power system.

II. 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]. Here, $+Q_{cap}$ is a fixed capacitance value, therefore the magnitude of reactive power injected into the system, Q_{net}, is controlled by the magnitude of $-Q_{ind}$ reactive power absorbed by the TCR. The basis of the thyristor controlled reactor (TCR) which conduct on alternate half-cycles of the supply frequency. If the thyristors are gated into conduction precisely at the peaks of the supply voltage, full conduction results in the reactor, and the current is the same as though the thyristor controller were short circuited. SVC based control system is shown in Fig.1[6].

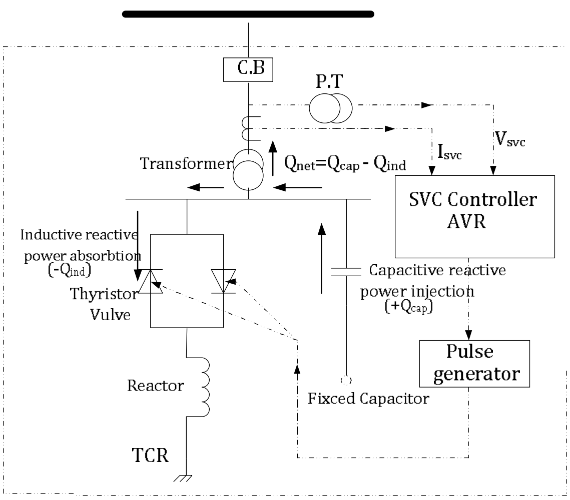

Figure 1 : SVC based control system

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III. SVC V-I CHARACTERISTICS

a) The SVC can be operated in two different modes

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.2[3].

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

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

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

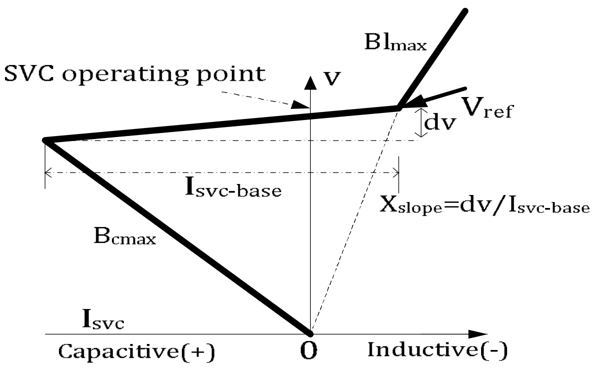

Figure 2 : Steady state(V-I) characteristic of a SVC

IV. POWER SYSTEM MODEL

This example described in this section illustrates modelling of a simple transmission system containing 2- hydraulic power plants[Fig.3]. SVC has been used to improve transient stability and power system oscillations damping. The phasor simulation method can be used. A single line diagram represents a simple 500 kV transmission system is shown in Fig.3[9].

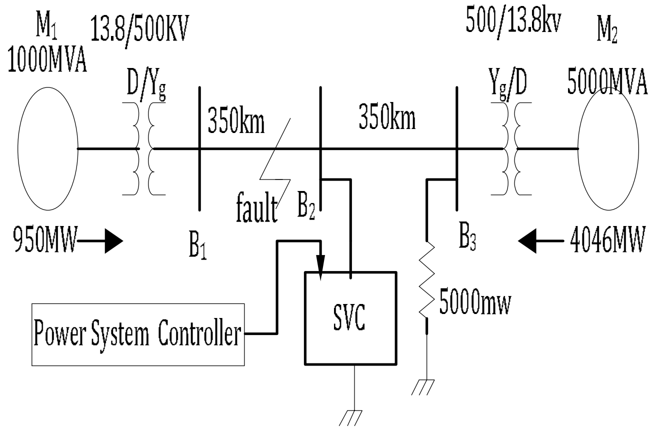

Figure 3 : Single line diagram of 2-machine power system

A 1000 MW hydraulic generation plant (M1) is connected to a load centre through a long 500 kV, total 700km transmission line. A 5000 MW of resistive load is modelled as the load centre. The remote 1000 MVA plant and a local generation of 5000 MVA (plant M2) feed the load. A load flow has been performed on this system with plant M1 generating 950 MW so that plant M2 produces4046 MW. The line carries 944 MW which isclose to its surge impedance loading (SIL = 977 MW).To maintain system stability after faults, the Transmissi online is shunt compensated at its centre by a 200MVAR Static VAR Compensator (SVC).

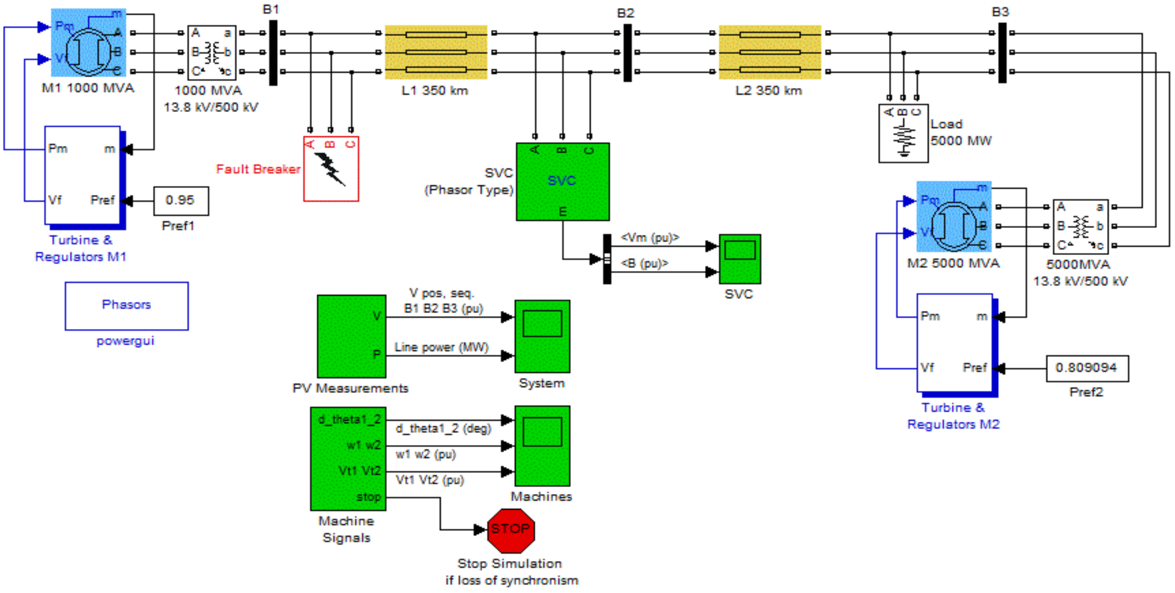

Figure 4 : Complete simulink model of 2-machine power system

The SVC does not have any controller unit. Machine & SVC parameters has been taken from reference[9].The complete simulink model of SVC with PID controller is shown in Fig.4. To maintain system stability after faults, the transmissionline is shunt compensated at its centre by a 200MVAR Static VAR Compensator (SVC) with PID controller. The two machines are equipped with a hydraulic turbine and governor (HTG), excitation system, and PID controller. Another machine is swing generator.PID is used in the model to add damping to the rotor oscillations of the synchronous machine by controlling its excitation current[5]. Any disturbances that occur in power systems due to fault, 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 stepping out of synchronism.

V. SIMULATION RESULTS

The load flow solution of the above system is calculated and the simulation results are shown below. Two types of faults: A. single line to ground fault & B. Three phase fault have been considered.

a) Single line to ground fault

Consider a 1-phase fault occurred at 0.1s & circuit breaker is opened at 0.2s (4-cycle fault), Without SVC, the system voltage, power & machines oscillates goes on unstable[Fig.(5,7,9)]. But if SVC(without controller) is applied then voltage becomes stable within 3s [Fig.6], power becomes within 3s[Fig.8] & machines oscillation becomes stable within 4.5s [Fig.10]. All results has been summarized in table-III

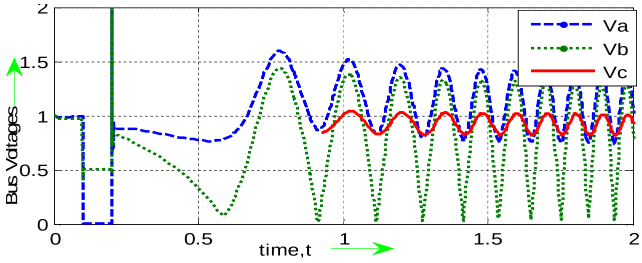

Figure 5 : Bus voltages in p.u for 1-phase fault(without SVC)

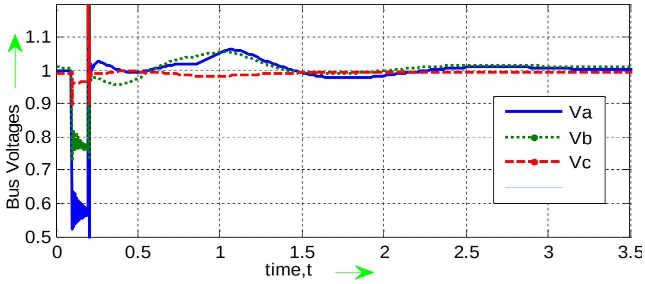

Figure 6 : Bus Voltages in p.u for 1-phase fault (with SVC)

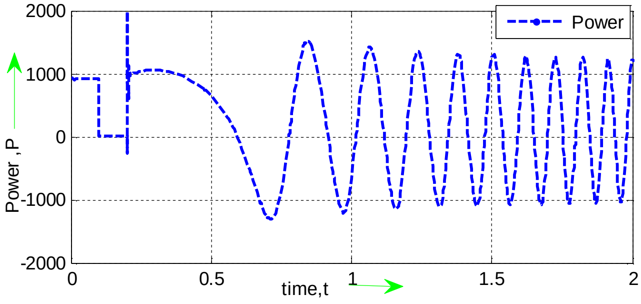

Figure 7 : Bus power, P in MW during fault (Without SVC)

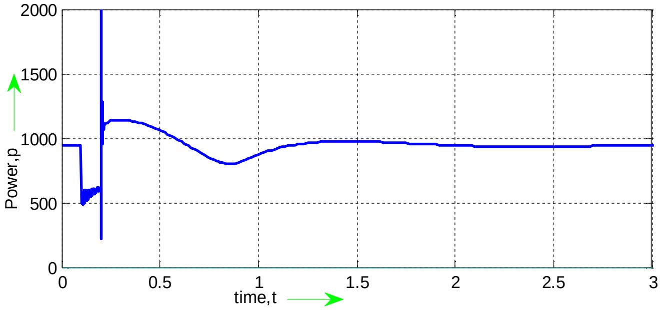

Figure 8 : Bus Power(P)in MW for 1-Ø faults(with SVC)

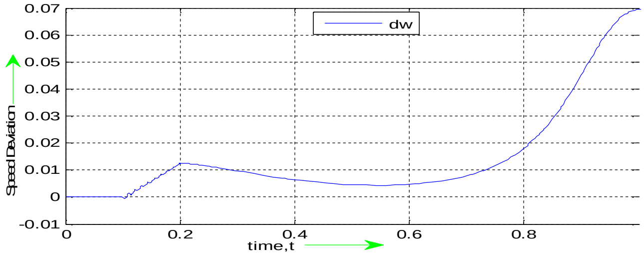

Figure 9 : Speed deviation for 1- phase fault(without SVC)

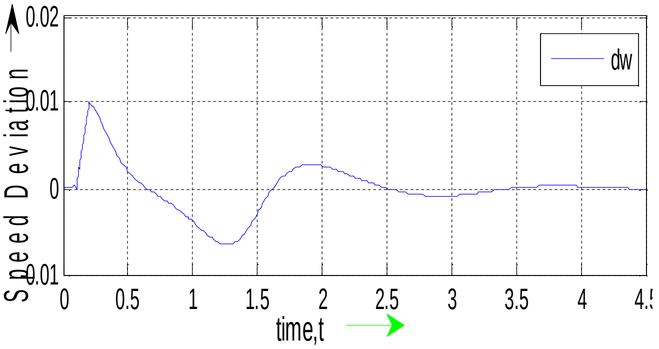

Figure 10 : Speed oscillations for 1- phase fault(with SVC)

b) Three phase fault

During 3-phase faults, If no SVC is applied then system voltage & machines speed deviations becomes unstable But when SVC(without controller) is applied then the system voltage becomes stable within 5s [Fig.11] & machines speed deviation becomes stable within 5s [Fig.12].

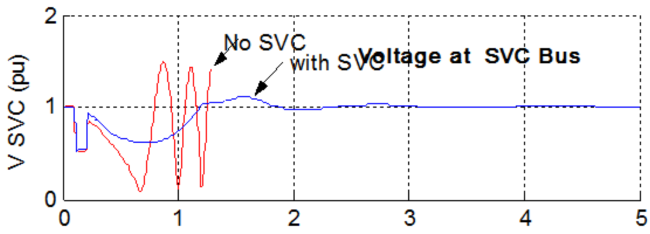

Figure 11 : Bus Voltage(Va) in p.u for L-L phase fault

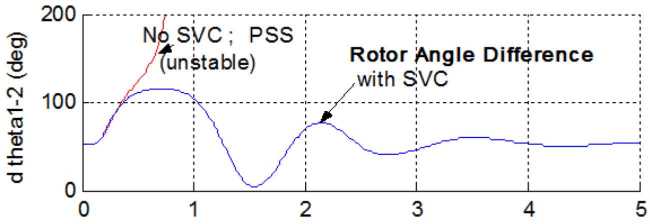

Figure 12 : Machines speed deviation for L-L fault

VI. DESIGNE OF CASCADE PROPOTIONAL INTEGRAL DIFFERTIONAL CONTROLLER (PID)

The Tyreus- Luyben procedure is quite similar to the Ziegler-Nichols method but the final controller settings are different. Tyreus-Luyben PID Controller, the values of delay time, rise time, and settling time are better in comparison with Modified Ziegler-Nichols method. Also this method only proposes settings for PI and PID controllers. These settings that are based on ultimate gain and period are given in table 1.

Table 1 : Tyreus-Luyben settings

Controller	Kp	Ti	Td
PI	Kcr/3.2	2.2Pcr	
PID	Kcr/3.2	2.2Pcr	Pcr/6.3

For some control loops the measure of oscillation, provide by ¼ decay ratio and the corresponding large overshoots for set point changes are undesirable therefore more conservative methods are often preferable such as modified Z-N settings

Table 2 : Modified Ziegler-Nichols settings

Controller	Kp	Ti	Td
PI	0.2Kcr	Pcr/2	
PID	0.2Kcr	Pcr/2	Pcr/3

a) *Designed of PID Controller*

PID controller is tuned by the proposed both Tyreus-Luyben tuning and modified Ziegler- Nichols methods. The PID controller has three term control signal

$$u(t) = K_p e(t) + \frac{K_p}{T_i}\int e(t)dt + K_p T_d \frac{de(t)}{dt}$$

$$\frac{\mathrm{U(s)}}{\mathrm{E(s)}} = \mathrm{K_p}\left(1 + \frac{1}{\mathrm{T_i}S} + \mathrm{T_d}S\right)$$

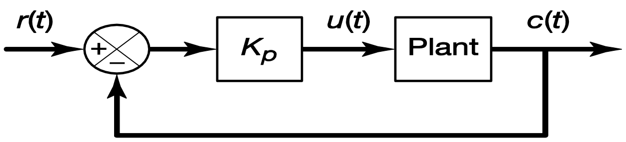

Figure 13 : PID controller is in proportional action

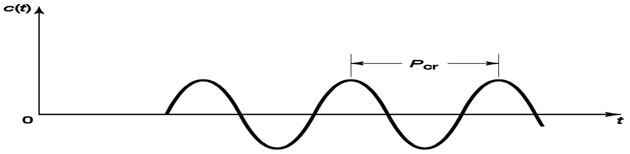

Figure 14 : Determination of sustained oscillation (P_{cr})

For selecting the proper controller parameters, Tyreus-Luyben Tuning Method is described below. In this method, the parameter is selected as $T_i=\infty, T_d=0$. Using the proportional controller action[Fig.14]only increase K_p from 0 to a critical value K_{cr}. At which the output first exhibits sustained oscillations [Fig.14]. Thus the critical gain K_{cr} & the corresponding period P_{cr} are experimentally determined.It is suggested that the values of the parameters K_p T_i T_d should set according to the following formula

$$K_p=0.3125K_{cr}\ ,\ T_i=2.2P_{cr}\ ,\ T_d=0.159P_{cr}$$

Notice that the PID controller tuned by proposed Tyreus-Luyben tuning methods rules as follows

$$\mathrm{Gc(s)=Kp}\left(1+\frac{1}{\mathrm{T_i}S} + \mathrm{T_d}S\right)$$

$$\mathrm{Gc(s)=0.3125Kcr}\left(1+\frac{1}{2.2PcrS}+0.159\mathrm{PcrS}\right)$$

It's found that, P_{cr}=0.2s & K_{cr}=200[Fig.5]. So,

$$\mathrm{Gc(s)}=\frac{1.98}{S} * (S^2 + 31.5S + 71.6)$$

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$$K_p=0.2K_{cr}\ ,\ T_i=0.5P_{cr}\ ,\ T_d=0.33P_{cr}$$

Notice that the PID controller tuned by proposed Ziegler-Nichols tuning methods rules as follows,

$$Gc(s)=Kp(1+\frac{1}{T_i S}+T_d S)$$

$$Gc(s)=0.2Kcr(1+\frac{1}{0.5PcrS}+0.33PcrS)$$

It's found that, P_{cr}=0.2s & K_{cr}=200[Fig.5]. So,

$$Gc(s)=\frac{2.67}{S}*(S^2+15S+150)$$

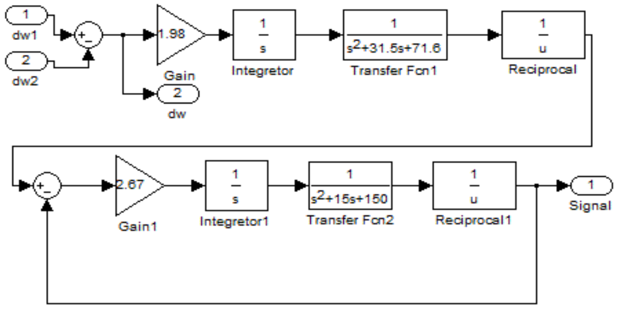

Figure 15 : Internal Structure of cascade PID controller with dω input

VII. SIMULATION RESULTS

The network remains same [Fig.4],just simple SVC is replaced by cascade PID controlled SVC. During fault ,machines speed deviation(dω) always monitored by cascade PID controller & taking input of this oscillation, after processing this signal reaches as Vref in SVC . it reduces damping of power system oscillation& helps SVC to improve stability. Two types of faults has been considered:

A. Single line to ground fault and B. Three phase L-L fault

a) Single line to ground fault

During 1-phase faults, if cascade PID is used with SVC controller then, the system voltage becomes stable within 1.5s with 0% damping [Fig.16] &Power (P,Q) becomes stable within 1.2s& 1s [Fig.17,18] & Machine speed deviationt dω becomes stable at 2.8s[Fig.19].

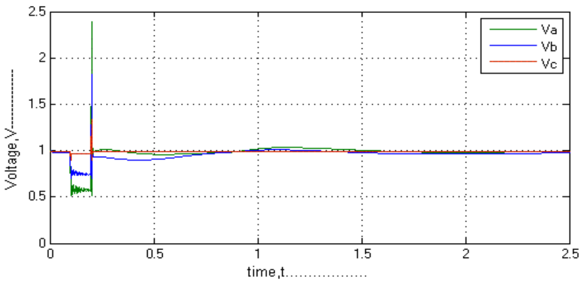

Figure 16 : Bus voltage in p.u for 1-Ø fault (with cascade PID)

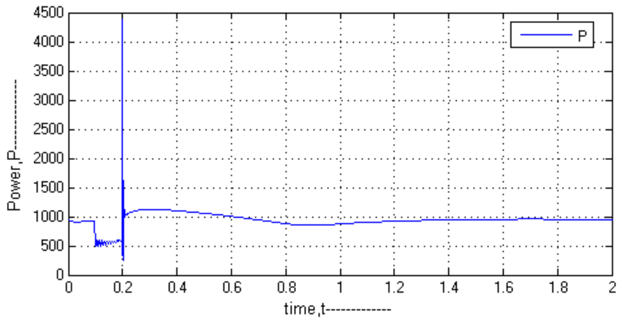

Figure 17 : Bus power,P in MW for 1-Ø fault (with cascade PID)

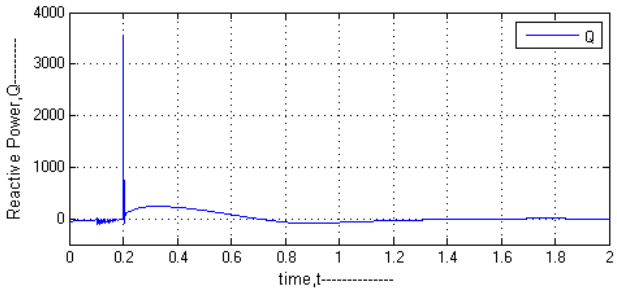

Figure 18 : Bus Power,Q for 1-Ø fault in MW(with cascade PID)

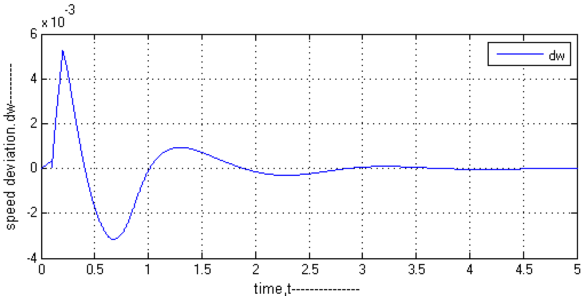

Figure 19 : Machines speed deviation for 1-Ø fault(with cascade PID)

b) Three phase fault

During 3-phase faults, If cascade PID is used with SVC controller then, the system voltage becomes stable within 2.5s [Fig.20] & Both power (P,Q) becomes stable within 1.8s [Fig.21,22].Machine speed deviation dω becomes stable at 3.3s[Fig.23].

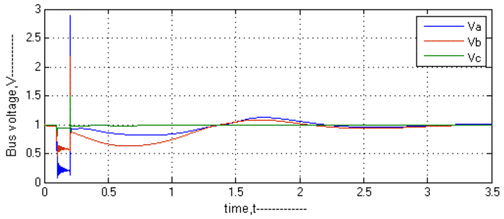

Figure 20 : Bus voltages in p.u for L-L fault (with cascade PID)

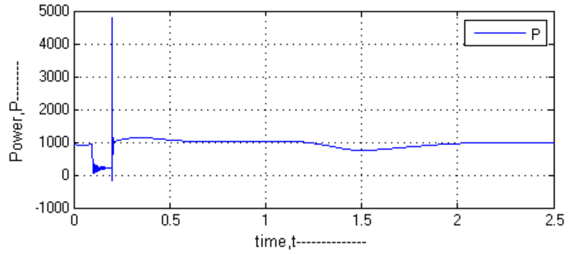

Figure 21 : Bus power, P in MW for L-L fault (with cascade PID)

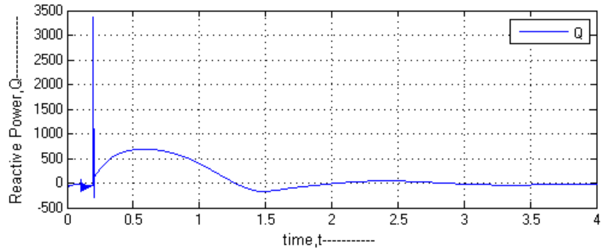

Figure 22 : Bus power, Q in MVAR for L-L fault (with cascade PID)

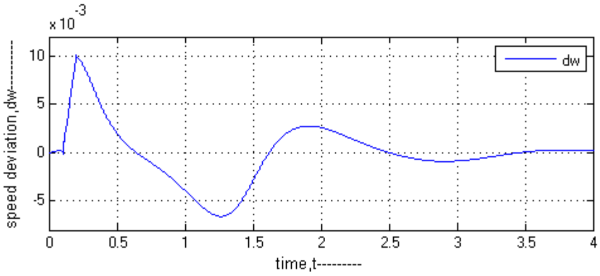

Figure 23 : Machines speed deviation for L-L fault(with cascade PID)

VIII. Results & Discussions

The performance of the proposed PID Controller with SVC has been summarized in the table III. In table-III, α (infinite time) means the system is unstable, SVC rating in MVA. The network is simulated in three steps; without SVC, With SVC, SVC with proposed CASCADE PID Controller.

Table 3 : Performance of proposed cascade PID

		1-Øfault (Stability time)			L-L fault (Stability time)		
Controller	SVC Rating	Volt	P,Q	dω	Volt	P, Q	dω
No SVC	200 MVA	α	α	α	α	α	α
SVC	200 MVA	3s	3s	4.5s	5s	5s	5s
SVC +Cascade PID	20 MVA	1.5s	1.2s ,1s	2.8s	2.5 s	1.8 s	3.3 s

IX. Conclusion

The obtained results of the conducted investigations along with the associated simulation demonstrated clearly that the proposed (desinged) cascade PID controller enhanced significantly the effectiveness of the integrated SVC in the examined power controller because of shorter stability time, simple designed system. In cascade PID Controller may be highly suitable as a SVC, low cost & highly efficient controller. The proposed cascade PID for SVC is proved to be very effective of robust power system within very shortest possible time for both steady state & dynamic conditions. These proposed cascade PID Controller can be applied for any interconnected multi-machine power system network for stability improvement.

These controller can be applied to another FACTS devices namely SSSC, STATCOM, UPFC whose controllers may be controlled externally by designing different types of controllers which also may be tuned by using different algorithm i.e. Fazzy logic,ANN, Genetic algorithm, FSO etc. for both transient and steady state stability improvement of a power system.

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