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Power System Stability Enhancement by Enhancing the Performance of SVC

Imran Azim[1],Habibur Rahman[2]

***Abstract*—This paper presents the model of a static VAR compensator (SVC) which is controlled externally by a Proportional Integral Differential (PID) controller for the improvements of voltage stability and damping effect of an on line power system. The PID controller parameters have been selected by using Cohen-Coon open loop tuning rule method. Both single phase and three phase faults have been considered in the research.Phasorsimulation method has been used & Simulation result shows that the SVC with PID controller is more effective to enhance the voltage stability and increases power transmission capacity of a power system. It has been observed that the SVC ratings are only 40 MVA with PID and 200 MVA without PID. The damping was 0.01% with PID controller in compared to that of 0.5% without PID. For single line to ground fault, Using PID the system voltage, power(P,Q), speed deviation(dω) becomes stable in 1.5s,0.6s,0.7s & 2s and without PID controller 3.5s, 3s & 4.5s respectively. Similarly, For L-L faults, Using PID the system voltage, power(P,Q),speed deviation(dω) becomes stable in 1.4s, 0.6s, 0.7s & 2.5s and without PID controller system becomes stable in 5srespectively. So with PID controller the system performance is greatly enhanced.**

Index Terms*—*Static VAR Compansator (SVC), PID Controller, AVR, TCR, Voltage regulation, MATLAB Simulink.

I. 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[2 3].Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to enhance same types of stability augmentation[2]. 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 used as it combines the advantages of both BJTS & MOSFETS.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[3]. 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. Authors also designed PI controller[6] and system performances were investigated.

Imran Azim:*Department Of EEE, Rajshahi University of Engineering&Technology,RUET.Bangladesh.*
MobileNo: +8801717210735

Habibur Rahman:*Department of EEE,Rajshahi University of Engineering & Technology,(RUET) Rajshahi-6204, Bangladesh, Mobile No: +8801758096759*

With a view to getting better performance PID controller has been designed for SVC to injectsV_{qref}externally. The dynamic nature of the SVC lies in the use of thyristor devices (e.g. GTO, IGCT)[4]. Therefore, thyristor based SVC with PID controllers have been used to improve the performance of multi-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[2].

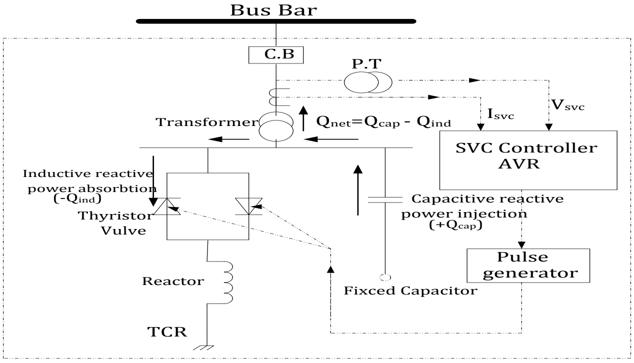

Fig.1 SVC based control system

III. SVC V-I CHARACTERISTICS

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.2[2,3],

$V=V_{ref}+X_s.I$,: In regulation range($-Bc_{max}<B<Bc_{max}$)
$V=I/Bc_{max}$, ,: SVC is fully Capacitive($B=Bc_{max}$)
$V=1/Bl_{max}$, : SVC is fully inductive($B=Bl_{max}$)

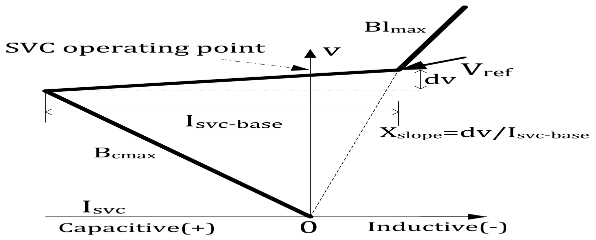

Fig.2 Steady state(V-I) characteristic of a SVC

IV. PID Controller Tuning Process

The process of selecting the controller parameters to meet given performance specifications is called PID tuning.

Most PID controllers are adjusted on-site, many different types of tuning rules have been proposed in the literature[1]. Using those tuning rules, delicate & fine tuning of PID controllers can be made on-site. Also automatic tuning methods have been developed and some of the PID controllers may possess on-line automatic tuning capabilities[1].

The PID controller has three term control signal[1],

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

In Laplace Form,

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

For selecting the proper controller parameters, Cohen-Coon open loop PID Tuning[8], Method is described below.

According to them, The process output is affected not only by the dynamics of the main process but also by the dynamics of the measuring sensor and final control element. They observed that the response of most processing unit to an input change had a sigmoidal shape. The sigmoidal shape can be adequately approximated by the responseof a first order system with dead time[3].

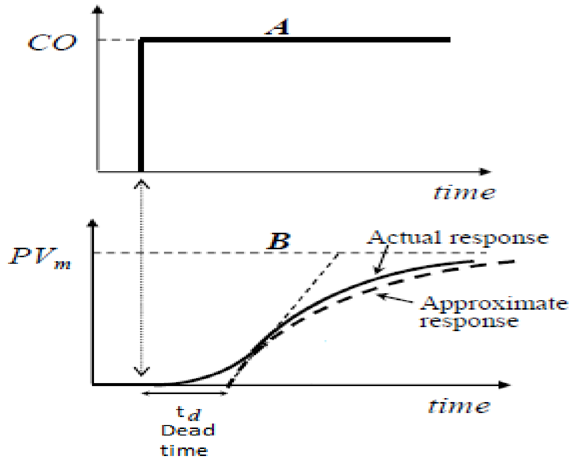

Fig.3 Response with Dead time

Once the value of process parameter are obtained, the PID parameter can be calculated from

$$K_p = \frac{1}{K}\frac{\tau}{td}\left(\frac{4}{3}+\frac{td}{4\tau}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where, K=B/A, τ=B/S

$$T_i = td\left(\frac{32+(\frac{6td}{\tau})}{13+(\frac{8td}{\tau})}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$T_d = \frac{4}{11+\frac{2td}{\tau}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

V. Modelling Of Power System With SVC

This example described in this section illustrates modeling of a simple transmission system containing 2- hydraulic power plants. 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.6.

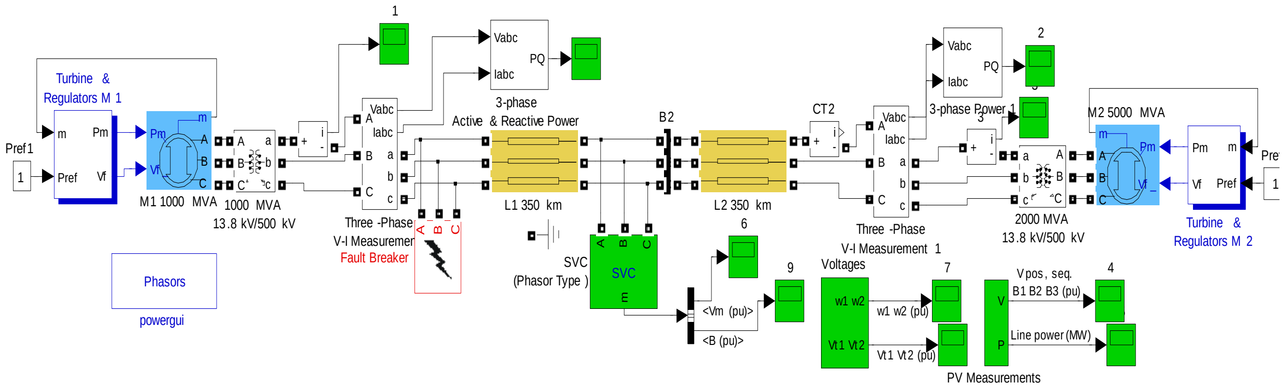

Fig.4 Complete simulink model of 2-machine power system

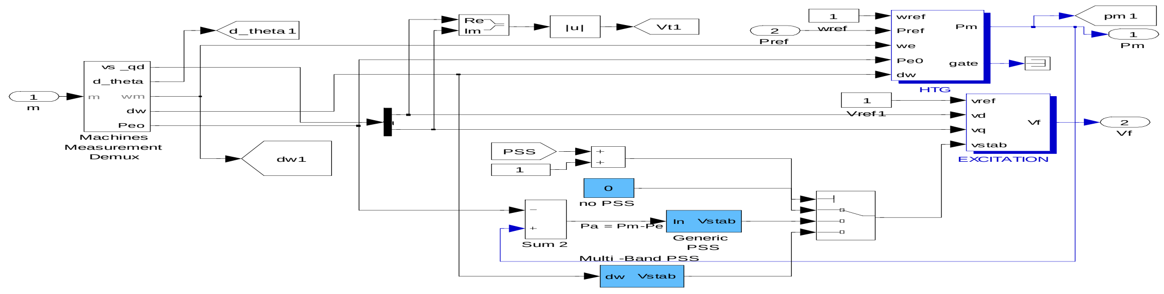

Fig.5 PSS, HTG and excitation system block diagram for machine

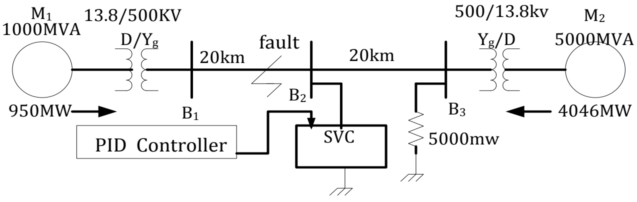

Fig.6 Single line diagram of 2-machine power

A 1000 MW hydraulic generation plant (M1) is connected to a load center through a long 500 kV, total 40km transmission line. A 5000 MW of resistive load is modelled as the load center. 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 produces 4046 MW. The line carries 944 MW which is close to its surge impedance loading (SIL = 977 MW).To maintain system stability after faults, the transmissionline is shunt compensated at its centre by a 200MVAR Static VAR Compensator (SVC). The SVC doesnot have any controller unit. Machine & SVC parameters has been taken from ref.[7].The complete simulink model of this network is shown in fig.4. To maintain system stability after faults, the transmissionline is shunt compensated at its center by a 200MVAR Static VAR Compensator (SVC). Thetwo machines are equipped with a hydraulic turbine and governor (HTG) [Fig.5],excitation system, and power system stabilizer (PSS). Another machine is swing generator.PSS is used in the model to add damping to the rotor oscillations of the synchronous machine by controlling its excitation current[3].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.

VI. SIMULATION RESULTS (WITHOUT PID)

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. L-L fault have been considered.

A. Single line to ground fault

Consider the 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.7(a-c-e)]. But if SVC(without PID) is applied then voltage becomes stable within 3s [Fig.7(b)],power becomes within 3s[Fig.7(d)] & machines oscillation becomes stable within 4.5s [Fig.7(f)]. The results has been summarized in table-I.

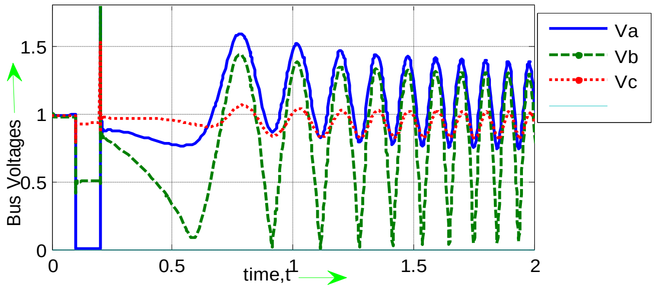

Fig. 7(a) Bus voltages in p.u for 1-phase fault(without SVC)

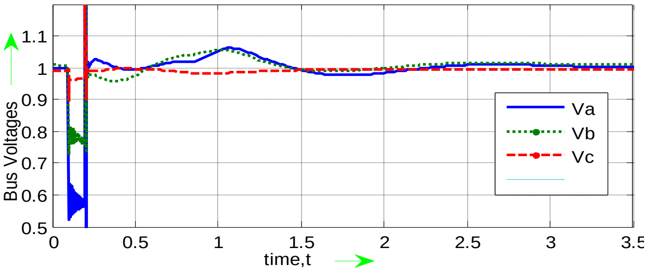

Fig. 7(b) Bus Voltages in p.u for 1-phase fault (with SVC)

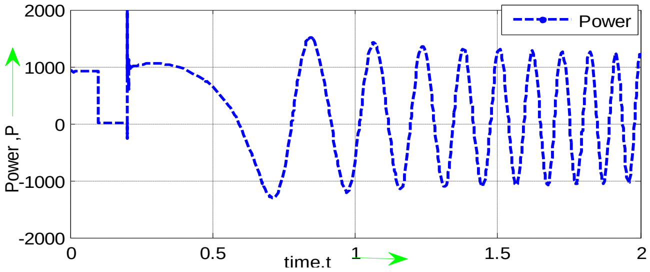

Fig. 7(c) Bus power,P in MW during fault(Without SVC)

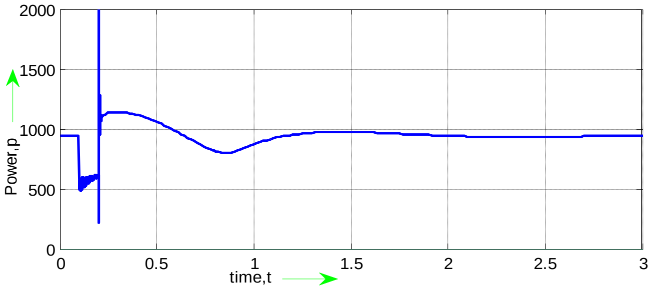

Fig . 7(d) Bus Power(P)in MW for 1-Ø fault(With SVC)

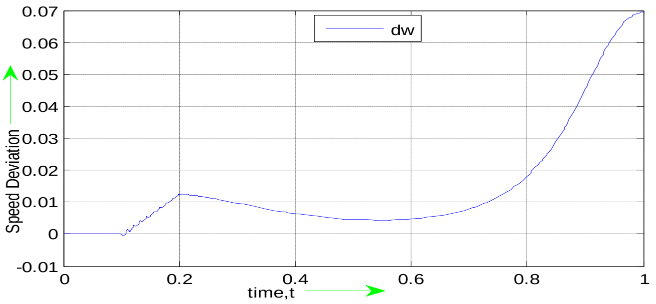

Fig. 7(e) Speed deviation for 1- phase fault(without SVC)

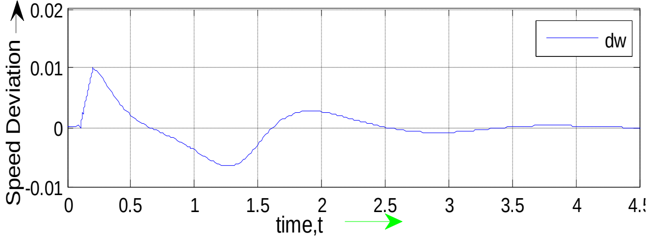

Fig. 7(f) Speed oscillations for 1- phase fault(with SVC)

B. Three Phase (Line-Line) fault

During 3-phase faults, If no SVC is applied then system voltage & machines speed deviations becomes unstable But when SVC(without PID) is applied then the system voltage becomes stable within 5s [Fig.8(a)] & machines speed deviation becomes stable within 5s [Fig.8(b)].

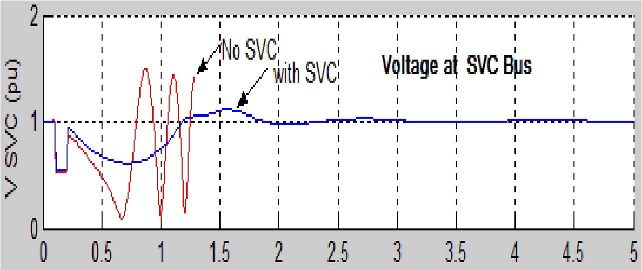

Fig.8(a) Bus Voltage(Va) in p.u for L-L phase fault

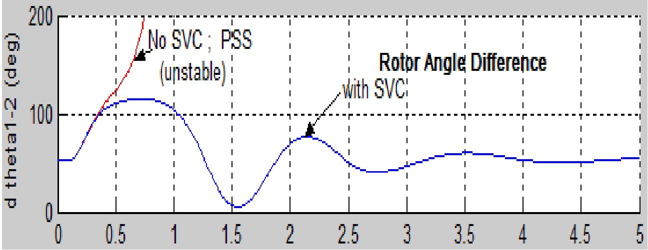

Fig. 8(b) Machines speed deviation for L-L fault

VII. MATLAB SIMULATION RESULTS

The proposed PID controller parameters has been designed by using Cohen-Coon open loop tuning method [sec. IV]. The parameters A & B are selected 200 & 40 respectively .whereas the time elapsed until the time responded is determined from Fig .7(a) & found t_d=0.2. Now, From [Eq. 1,2,3&4] it is found that

$$\frac{U(S)}{E(S)}=\frac{(S+545)^2(S+0.25)^2}{S^2(S+10800)^2}$$

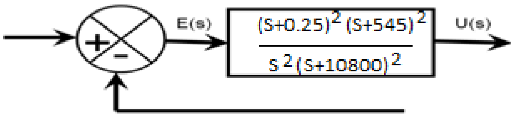

Fig.9 PID controller with tuning parameters

During faults the machines angular speed deviation(dω) line voltage ,line current, power all are changed. So, dω & pm are taken as the input parameters of newly designed PID controller. The proposed PID controlled SVC simulink model is shown in the Fig.10(a-b).

VIII. SIMULATIONRESULT (WITH PID)

The network remains same [Fig.4],just simple SVC is replaced by PID controlled SVC[Fig.10(b)].During fault, when the parameters speed deviation dω is monitored by PID controller & taking input of those oscillation, after processing as shown infig.10(a).PID reduces damping of power system oscillation.

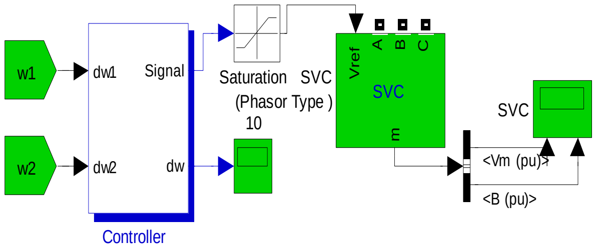

Fig.10(b) PID controlled SVC simulink model with dω input

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 PID is used as SVC controller then, the system voltage becomes stable within 1.5s with 0% damping [Fig.11(a)] & Machines speed deviation becomes stable within 2s [Fig.11(b)] & Both power (P,Q) becomes stable within 0.6s & 0.7s respectively [Fig.11(c-d)].

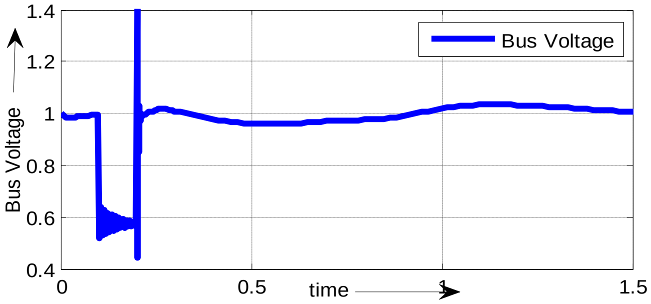

Fig. 11(a) Bus voltage in p.u for 1-Ø fault (with PID)

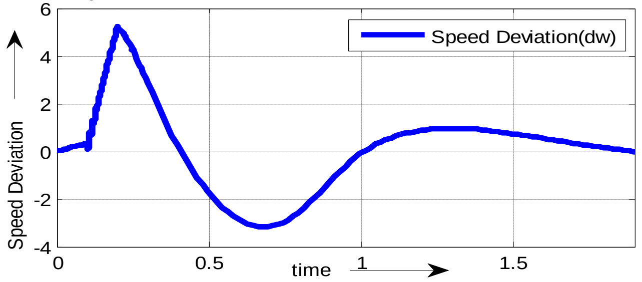

Fig. 11(b) Machines speed deviation for 1-Ø fault(with PID)

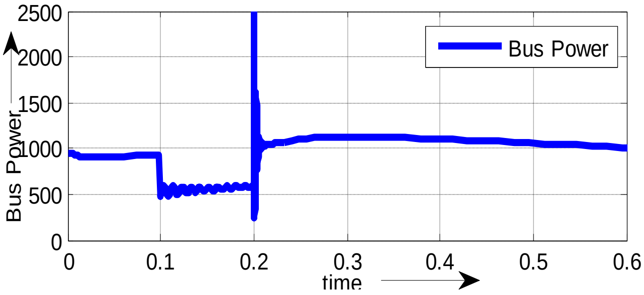

Fig. 11(c) Bus power,P in MW for 1-Ø fault (with PID)

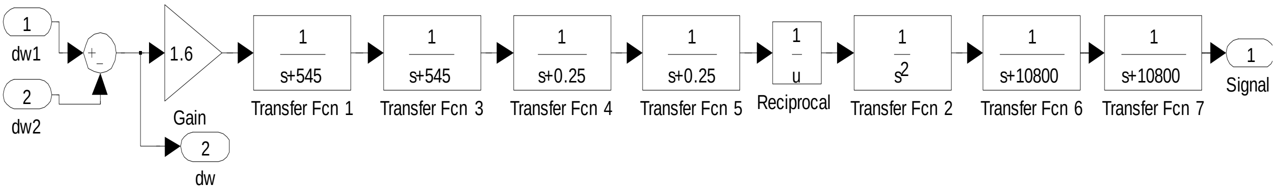

Fig. 10(a) Internal Structure of PID controller siulink model with dω input.

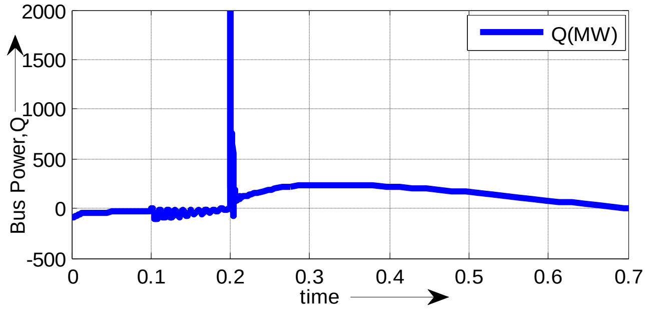

Fig. 11(d) Bus power,Q in MVAR for 1-Ø fault (with PID)

B. Three Phase (Line-Line) fault

During 1-phase faults, if PID is used as SVC controller then, the system voltage becomes stable within 1.4s with 0% damping [Fig.12(a)] & Machines speed deviation becomes stable within 2.5s [Fig.12(b)] & Both power (P,Q) becomes stable within 0.6s & 0.7s respectively [Fig.12(c-d)].

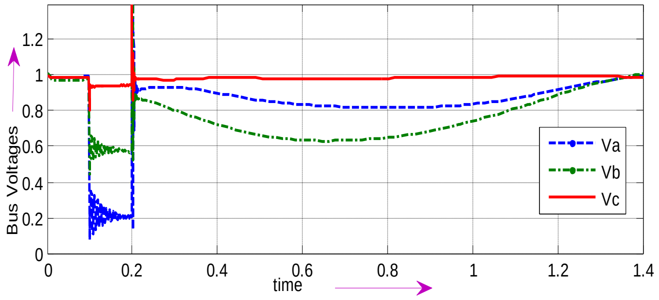

Fig. 12(a) Bus voltages in p.u for L-L fault (with PID)

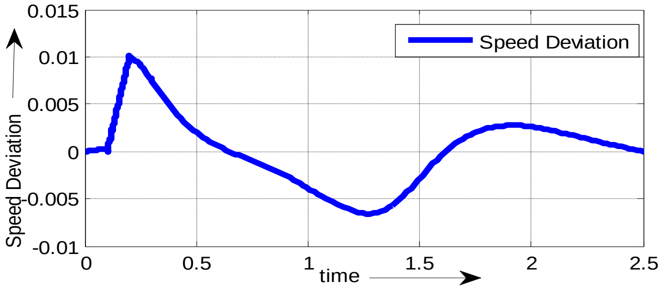

Fig. 12(b) Machines speed deviation for L-L fault(with PID)

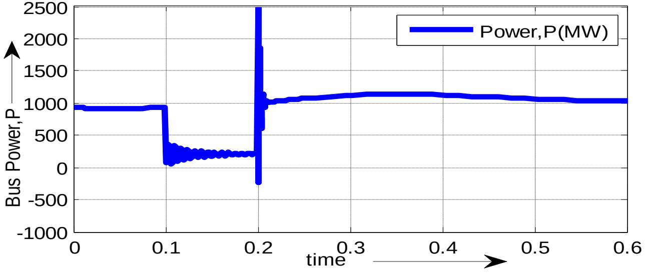

Fig. 12(c) Bus power, P in MW for L-L fault (with PID)

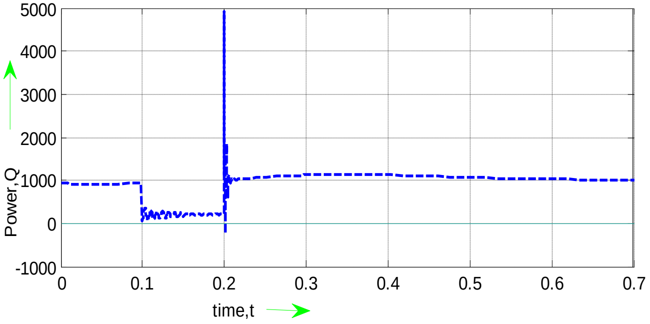

Fig. 12(d) Bus power, Q in MVAR for L-L fault (with PID)

Table-I
Performance analysis of PID controller

		1-Øfault (st.time)			L-Lfault(st.time)		
controller	SVC rating	volt	dω	P,Q	volt	dω	P,Q
No SVC	200MVA	α	α	α	α	α	α
SVC	200MVA	3.5 s	4.5 s	3s	5s	5s	5s
SVC+ PID	40MVA	1.5 s	2s	0.6 0.7	1.4 s	2.5 s	0.6 0.7

IX. CONCLUSION

This paper presents the stability improvement of voltage level, machine oscillation damping, real & reactive power in a power system model of SVC with or without properly tuned PID controller for different types of faulted conditions. PID is also a very efficient controller for SVC to enhance the power system stability. From above results, this proposed PID controller which is tuned by using Cohen-Coon open loop tuning method 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 PID 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.

Another FACTS devices namely SSSC, STATCOM, UPFC whose controllers may be controlled externally by designing different types of controllers for both transient and steady state stability improvement of a power system.

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AUTHOR'S BIOGRAPHIES

Md. Imran Azim is currently a final year student of bachelor of Science in Electrical & Electronic Engineering in Rajshahi University of Engineering & Technology (RUET), Bangladesh. The author has keen interest to research in power electronics& Smart Grid system.(*Email: imran.azim89@gmail.com*)

Md.Habibur Rahmanhas completed his bachelor of Science in Electrical & Electronic Engineering in Rajshahi University of Engineering & Technology (RUET),Rajshahi-6204,Bangladesh. The author's has total number of ten publications in differentInternational Journal& 3 text book on power system stability which has published in LAP lambert, Germeny. Habibis interested to research in the field of stabilization of power system, FACTS devices, Genetic Algorithm, Fuzzy Logic, Microstrip Patch Antenna. (Email: *habibieee@yahoo.com*).