ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering &Technology (IJARCET)
Volume 1, Issue 8, Octber 2012

Power System Stability Improvement By Using SVC With TID Tuned PID Controller

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***Abstract*—This paper presents the model of a static VAR compensator (SVC) which is controlled externally by a Proportional IntegralDifferential(PID)controller for the improvements of power system stability and damping effect of an on line power system. PID parameters has been optimized by proposed Triple Integral Differential(TID) close loop tuning method. Both single phase and three phase (L-L) faults have been considered in the research. In this paper, A power system network is considered which is simulated in the phasor simulation method & the network is simulated in three steps; without SVC, With SVC but no externally controlled, SVC with TID tuned PID controller . Simulation result shows that without SVC, the system parameters becomes unstable during faults. When SVC is imposed in the network, then system parameters becomes stable. Again, when SVC is controlled externally by PID controllers, then system parameters(V,P,Q,dω) becomes stable in faster way then without controller. It has been observed that the SVC ratings are only 20 MVA with controllers and 200 MVA without controllers. So, SVC with TID tuned PID controllers are more effective to enhance the voltage stability and increases power transmission capacity of a power system .The power system oscillations is also reduced with controllers in compared to that of without controllers. So with controllers the system performance is greatly enhanced.**

Keywords—Static VARCompansator (SVC), voltage regulator,PID controller, TID Tuning, 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[1-2].Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to enhance same types of stability augmentation[3]. 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 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. In previous study Authors has designed a PID controller with Ziegler-Nicholsclose loop tuning[4]. However, in this study, With a view to get better performance, PID ontroller parameters has been tuned by proposed Triple Integral Differential(TID) close loop tunng method for SVC to injects V_{qref}externally. The dynamic nature of the SVC lies in the use of thyristor devices (e.g. GTO, IGCT)[3]. 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[3].

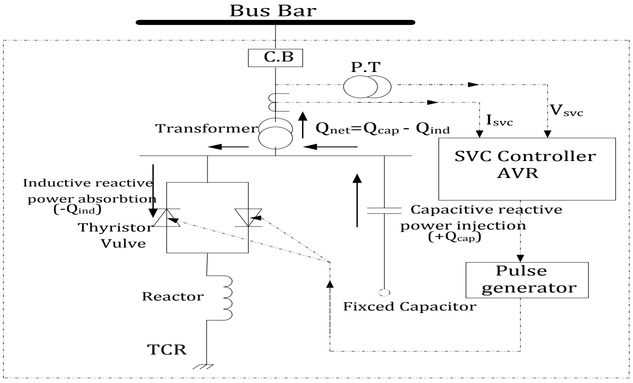

Fig.1 SVC based control system

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[3],

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$V=V_{ref}+X_s.I$,: 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($B=Bl_{max}$)

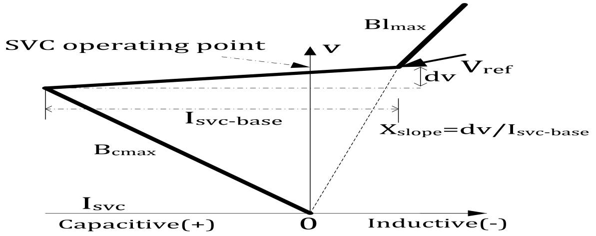

Fig.2 Steady state(V-I) characteristic of a SVC

IV. 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[5].

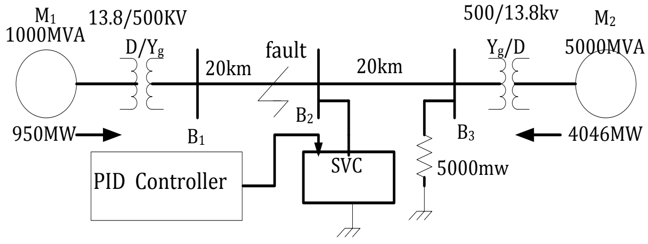

Fig.3 Single line diagram of 2-machine power

A 1000 MW hydraulic generation plant (M1) is connected to a load centre through a long 500 kV, total 40km 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 systemwith 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 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 reference[5].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 centre by a 200MVAR Static VAR Compensator (SVC). Thetwo machines are equipped with a hydraulic turbine and governor (HTG) [Fig.6],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[2]. 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.(5,8,10)]. But if SVC(without controller) is applied then voltage becomes stable within 3s [Fig.7],power becomes within 3s[Fig.9] & machines oscillation becomes stable within 4.5s [Fig.11]. All results has been summarized in table-I.

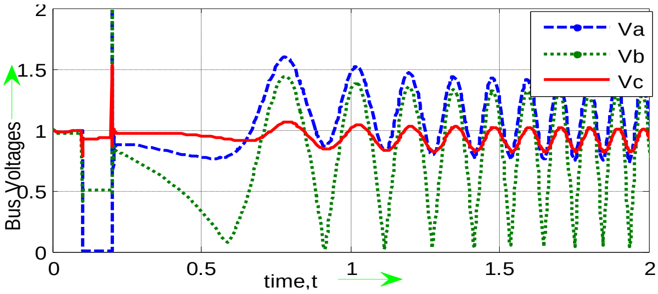

Fig. 5 Bus voltages in p.u for 1-phase fault(without SVC)

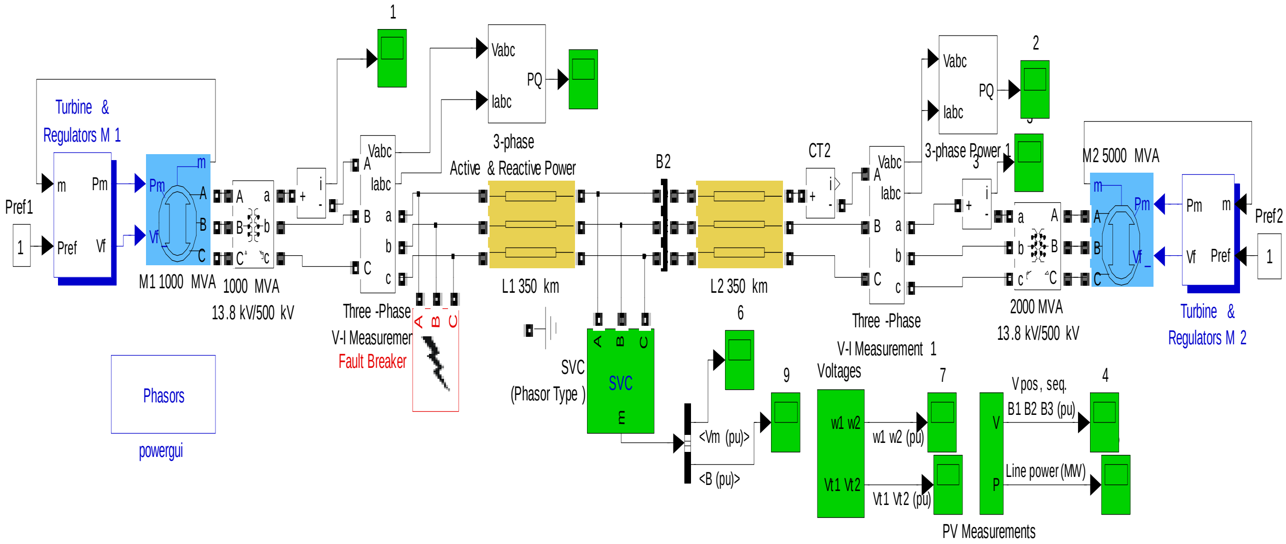

Fig.4 Complete simulink model of 2-machine power system

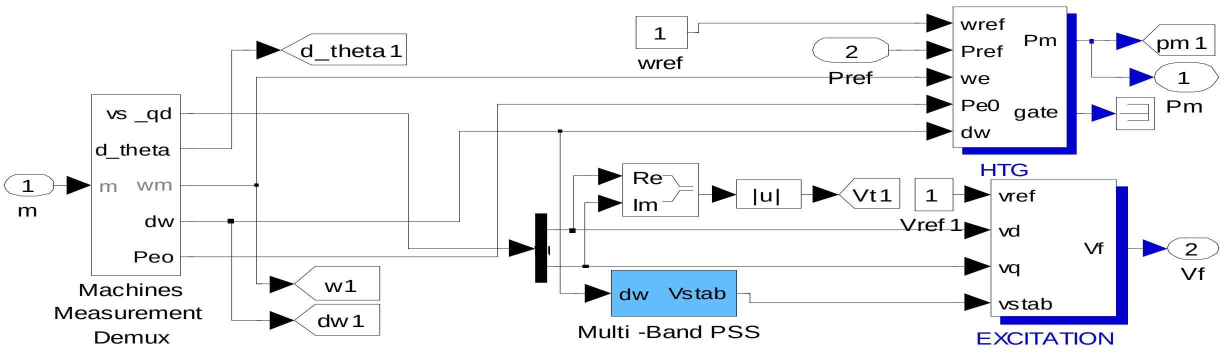

Fig.6 PSS, HTG and excitation system block diagram for machine 1.

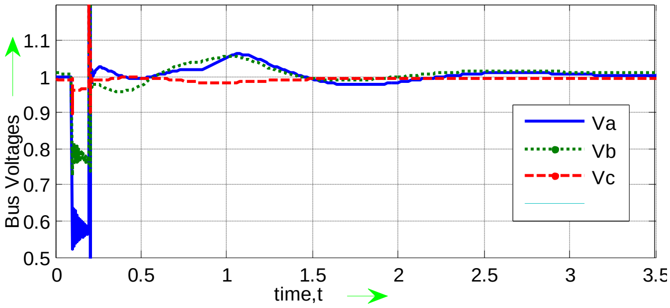

Fig.7 Bus Voltages in p.u for 1-phase fault (with SVC)

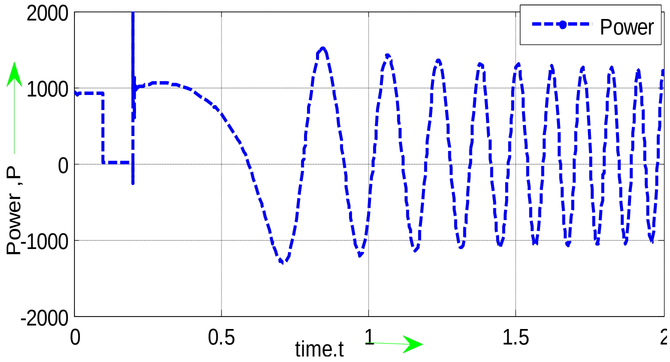

Fig.8 Bus power,P in MW during fault (Without SVC)

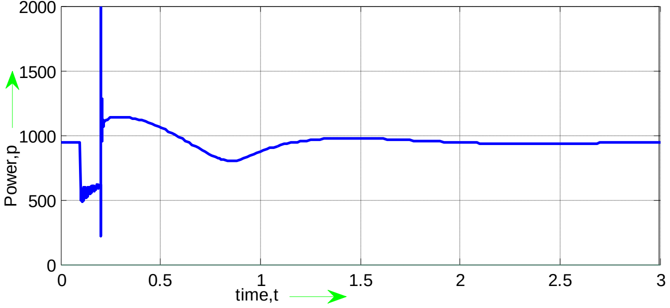

Fig.9 Bus Power(P)in MW for 1-Ø faults(with SVC)

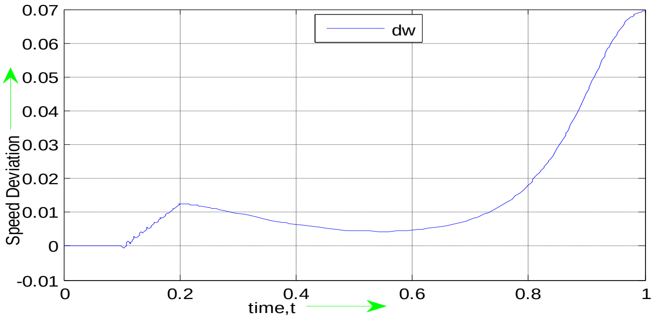

Fig.10 Speed deviation for 1- phase fault(without SVC)

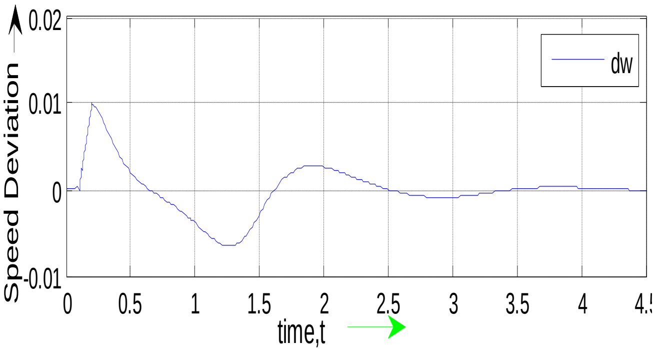

Fig.11 Speed oscillations for 1- phase fault(with SVC)

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.12] & machines speed deviation becomes stable within 5s [Fig.13].

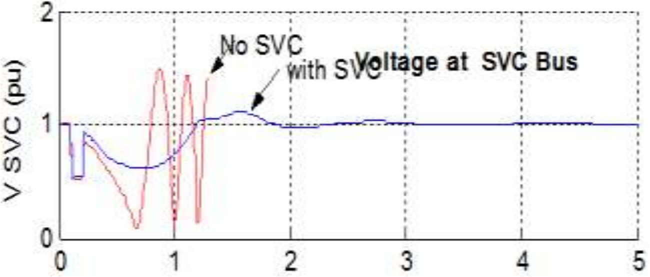

Fig.12 Bus Voltage(Va) in p.u for L-L phase fault

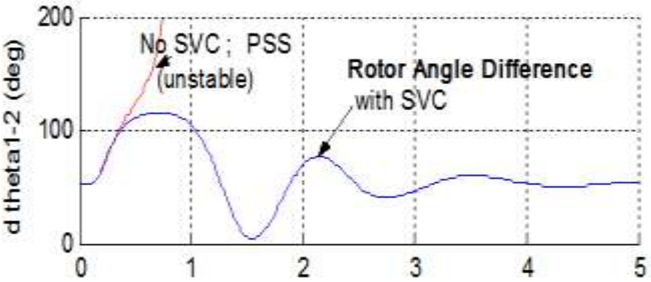

Fig.13 Machines speed deviation for L-L fault

VI. DESIGNE OF PID CONTROLLER WITH TID TUNED

The process of selecting the controller parameters to meet given performance specifications is called PID tuning. Here, PID controller is tuned by the proposed Triple Integral Differential(TID) tuning methods .

The PID controller has three term control signal,

$$u(t) = K_p e(t) + \frac{K_p}{T_i} \iiint e(t)dt + K_p T_d \frac{d^3 e(t)}{dt^3} \quad (1)$$

In Laplace Form,

$$\frac{U(s)}{E(s)} = K_p \left(1 + \frac{1}{T_i S^3} + T_d S^3 \right) \quad (2)$$

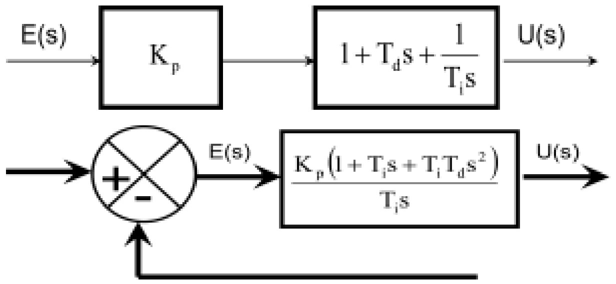

Fig.14 Block diagram of PID controller parameters

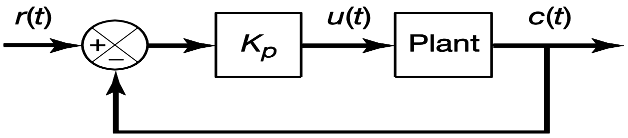

Fig.15 PI controller is in proportional action

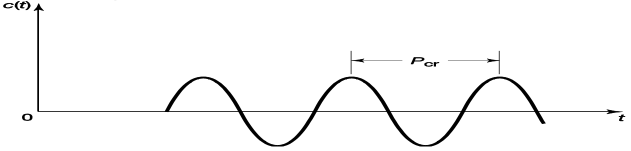

Fig.16 Determination of sustained oscillation (P_{cr})

For selecting the proper controller parameters, TID 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.15]only increase K_p from 0 to a critical value K_{cr}. At which the output first exhibits sustained oscillations[Fig.16]. 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 same as Zieglar-Niclesmethods[4].

$K_p=0.6K_{cr}$, $T_i=0.5P_{cr}$, $T_d=0.125P_{cr}$

Notice that the PID controller tuned by proposed TID tuning methods rules as follows, From Eq.2,

$$G_C(s) = K_p \left(1 + \frac{1}{T_i S^3} + T_d S^3 \right) \quad (3)$$

$$G_C(s) = 0.6K_{cr} \left(1 + \frac{1}{0.5 P_{cr} S^3} + 0.125 P_{cr} S^3 \right) \quad (4)$$

$$G_C(s) = 0.6K_{cr} S * 0.125 P_{cr} \left(S^2 + \frac{1}{0.5 P_{cr} S^2 0.125 P_{cr}} + \frac{1}{S * 0.125 P_{cr}} \right) \quad (5)$$

$$G_C(s) = 0.075 * K_{cr} P_{cr} S \left(S^2 + \frac{16}{P_{cr}^2 S^4} + \frac{8}{P_{cr} S} \right) \quad (6)$$

$$G_C(s) = 0.075 K_{cr} P_{cr} S \left(S^2 + 2 * \frac{4}{P_{cr} S^2} S + (\frac{4}{P_{cr} S^2})^2 \right) \quad (7)$$

$$G_C(s) = 0.075 * K_{cr} P_{cr} S \left(S + \frac{4}{P_{cr} S^2} \right)^2 \quad \ldots\ldots\ldots\ldots\ldots(8)$$

$$G_C(s) = 0.075 * K_{cr} P_{cr} S \left(\frac{P_{cr} S^3 + 4}{P_{cr} S^2} \right)^2 \quad \ldots\ldots\ldots\ldots\ldots(9)$$

$$G_C(s) = \frac{0.075 * K_{cr} P_{cr}}{S} \left(\frac{P_{cr} S^3 + 4}{P_{cr} S} \right)^2 \quad \ldots\ldots\ldots\ldots(10)$$

$$G_C(s) = \frac{0.075 * 200 * 0.2}{S} \left(\frac{0.2S^3 + 4}{0.2 * S} \right)^2 \quad \ldots\ldots\ldots\ldots(11)$$

$$G_C(s) = \frac{3}{S} \left(\frac{0.2S^3 + 4}{0.2 * S} \right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

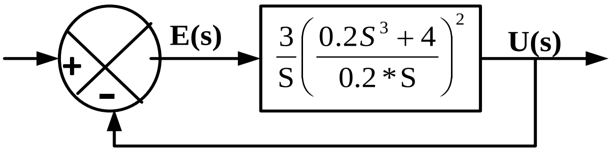

Fig.17 PID controller Tuning parameters

VII. SVC WITH PID CONTROLLER

The PID controller has been designed based on the above TID method which has shown in Fig.18,19,20,21.

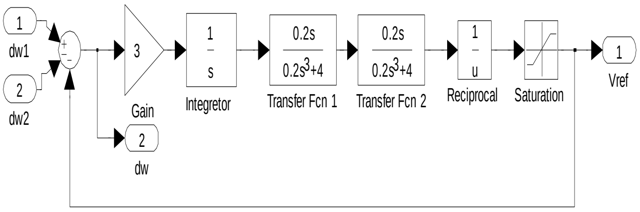

Fig.18 Internal Structure of PID controller with dω input

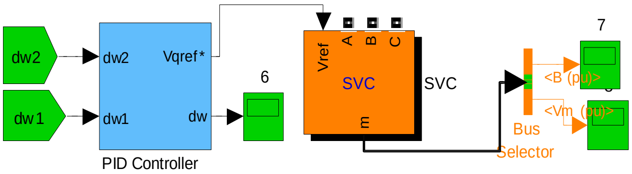

Fig.19 PID controlled SVC simulink model with dω input

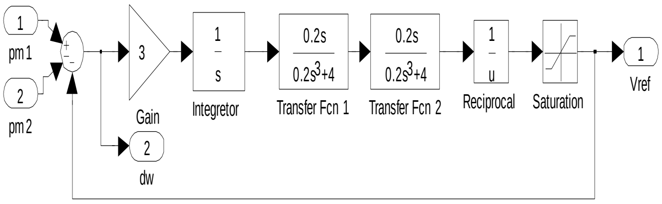

Fig.20 Internal Structure of PID controller with pm input

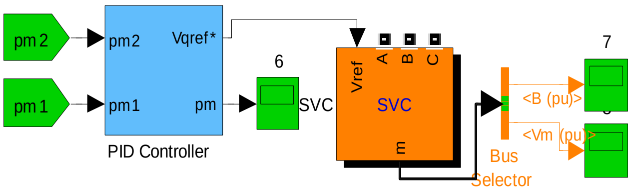

Fig.21 PID controlled SVC simulink model with pm input

VIII. SIMULATION RESULTS

The network remains same [Fig.4],just simple SVC is replaced by PID controlled SVC[Fig.19,21)]. During fault, when the parameters speed deviation(dω)& mechanical power deviation, pm always monitored by PID controller & taking input of those oscillation, after processing as shown in fig.18, PID reduces damping of power system oscillation. 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 0.9s with 0% damping [Fig.22] & Machines speed deviation becomes stable within 0.99s [Fig.24] & Power (P) becomes stable within 0.9s [Fig.23].

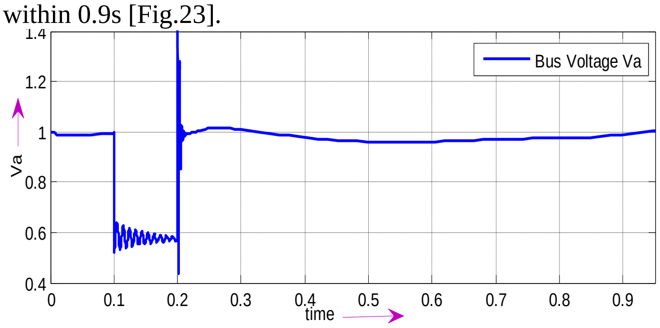

Fig.22 Bus voltage in p.u for 1-Ø fault (with PID)

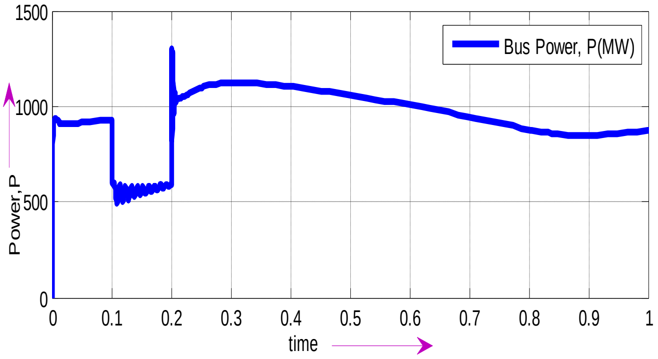

Fig.23 Bus power,P in MW for 1-Ø fault (with PID)

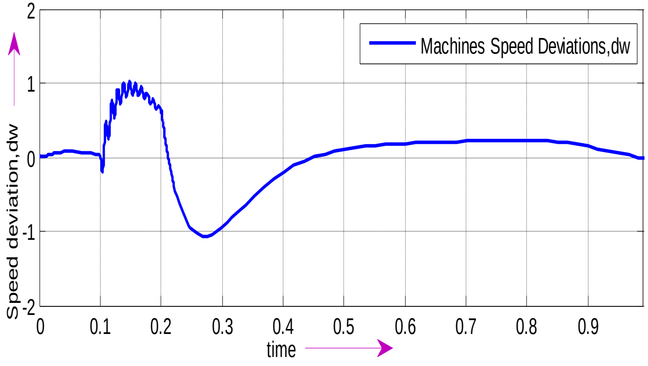

Fig.24 Machines speed deviation for 1-Ø fault(with PID)

B. Three phase fault

During 3-phase faults, If PID is used as SVC controller then, the system voltage becomes stable within 1.4s with 0% damping [Fig.25] & Machines speed deviation becomes stable within 0.8s [Fig.27] & Both power (P,Q) becomes stable within 0.5s [Fig.26,27].

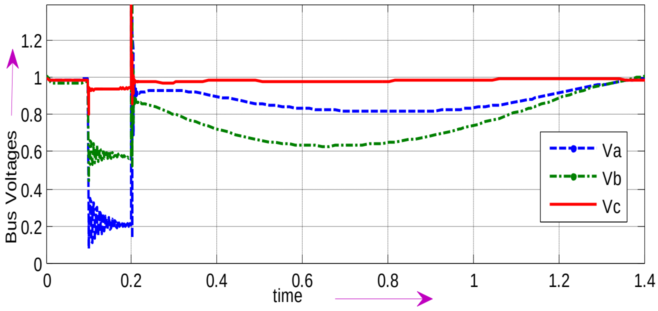

Fig.25 Bus voltages in p.u for L-L fault (with PID)

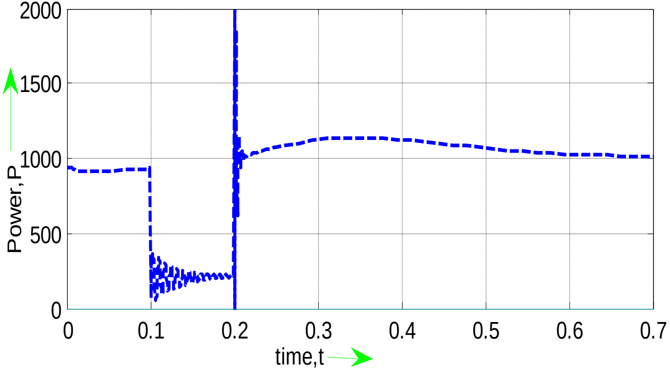

Fig.26 Bus power, P in MW for L-L fault (with PID)

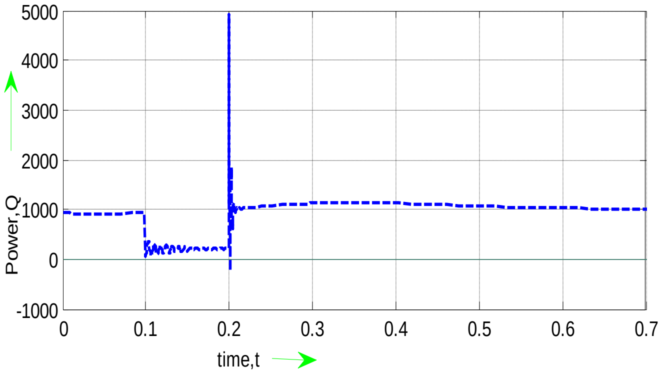

Fig.27 Bus power, Q in MVAR for L-L fault (with PID)

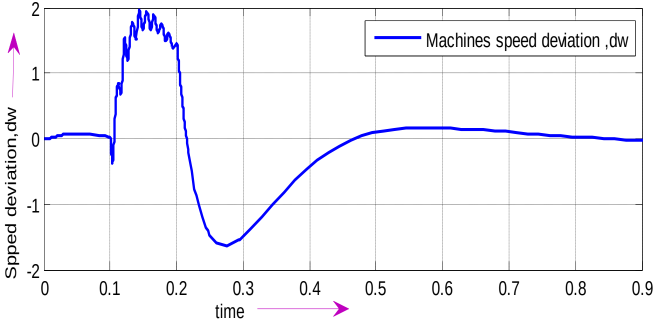

Fig.27 Machines speed deviation for L-L fault(with PID)

IX. RESULTS & DISCUSSIONS

The performance of the proposed TID tuned PID controller of power system network with SVC has been summarized in the table-I. In table-I, 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 TID tuned PIDcontroller.

Table-I
Performance ofproposed TID tuned PID Controller

		1-Øfault (Stability time)			**L-L fault (Stability time)**		
Controller	SVC MVA	volt	P	dω	volt	P,Q	dω
No SVC	200	α	α	α	α	α	α
SVC	200	3s	3s	4.5s	5s	5s	5s
SVC+ PID	20	0.9s	0.9s	0.99s	1.4 s	0.5 s	0.8 s

X. CONCLUSION

This paper presents the power system stability improvement i.e. voltage level, machine oscillation damping, real & reactive power in a power system model of SVC without or with proposed TID 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 Triple Integral Differential(TID) close loop tuning method for selecting PID controller parametersmay 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. These proposed TID methods can be applied for any interconnected multi-machine power system network.

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.

ACKNOWLEDGMENT

The authors would like to thanks specially to Dr. Md. Rafiqul Islam Sheikh, Professor & Head, Dept. of EEE, RUET for providing his innovative ideas, encouragement & observation for completing this research.

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