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Combined Operation of PSS And SVC For Power System Transient Stability Enhancement

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ABSTARCT

In this paper, improvement of transient stability by coordination of PSS (Power System Stabilizer) and SVC (Static var Compensator) has been observed. For this purpose a 9 bus multi machine system has been considered. Transient stability improvement has been tested subjected to three phase fault at bus 7 after 0.5 second and fault has been cleared after 1 second. By the use of PSS and SVC for the test system the electromechanical oscillation for generator electrical power has been reduced and the steady state power transfer has been enhanced.

Keywords : Transient stability, ETAP, PSS, Exicter,SVC.

INTRODUCTION

Power system stability has been recognized as an important problem for secure system operation. Transient instability has been the dominant stability problem on most systems, and has been the focus of much of the industry's attention concerning system stability. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged. For example, voltage stability, frequency stability and interarea oscillations have become greater concerns than in the past.

Classification of power system stability-

For convenience of analysis, stability problems are Generally divided into two major categories:

- Steady-state stability
- Transient stability

The steady state stability is the stability of the system under conditions of gradual or relatively slow change in load. The load is assumed to be applied at a rate which is slow when compared either with the natural frequency of oscillation of the major parts of the system or with the rate of change of field flux in the rotating machine in response to change in loading.

The transient state stability refers to the maximum flow of power possible through a point without losing the stability with sudden and large changes in the network conditions such as brought about by faults, by sudden large increment of loads.

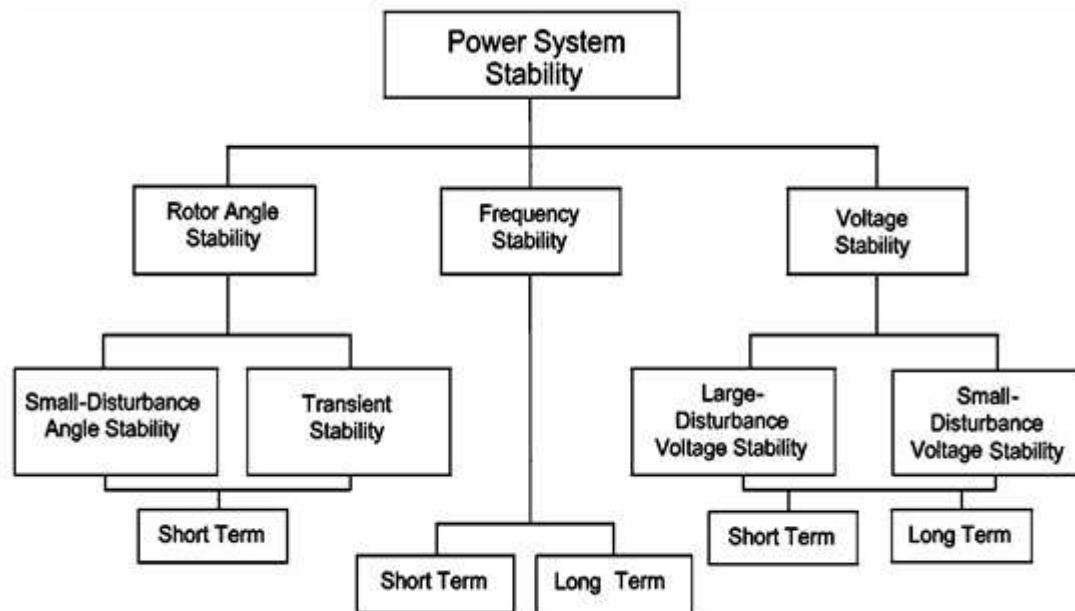


Fig-(1) classification of power system stability[1]

MATERIALS AND METHODS

Transient stability analysis-

A fault in the system will lead to instability and the machine will fall out of synchronism. If the system can't sustain till the fault is cleared, then the whole system will be in stabilised. During the instability not only the oscillation in rotor angle around the final position goes on increasing but also the change in angular speed. In such a situation the system will never come to its final position. The unbalanced condition or transient condition may leads to instability where the machines in the power system fall out of synchronism.

The system is subjected to a large variety of disturbances. The switching on and off of an appliance in the house is also a disturbance depending upon the size and capability of the interconnected system. Large disturbances such as lightning strokes, loss of transmission line carrying bulk power do occur in the system. Therefore transient stability is defined as the ability of the power system to survive the transition following the large disturbance and to reach an acceptable operating condition.

The physical phenomenon that occurs during a large disturbance is that there will be an imbalance between the mechanical power input and the electrical power output. This will tend to run the generator at high speed. The result will be the loss of synchronism of the generator and the machine will be disconnected from the system. This phenomenon is referred to as a generator going out of step.

The Etap Transient Stability Analysis is designed to investigate the system dynamic response disturbance. The program models dynamic characteristics of a power system, implements the user-defined events and action, solves the system network equation and machine differential equation interactively to find out system and machine response in time domain.

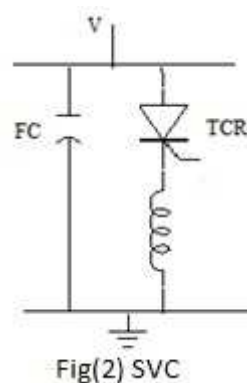
In this paper improvement of transient stability analysis of 9-bus multi machine system by using the coordinated effect of power system stabilizer (PSS), static var compensator (or SVC). In this analysis we create a three phase fault on specified bus and then investigation is to analyse the behaviour of the synchronous machine. For this work we used the licensed packaged of ETAP software.

The paper is organised as follows: section 2 gives a brief introduction of power system stabilizer (or PSS) and static var compensator (or SVC) and exciter which has been used. A 9-bus multi machine system or test system is described In section 3. The computer simulation results for system under study are presented and discussed in Section 4 and in Section 5 conclusions are given.

Implementation of SVC and PSS:-

Static var compensators are shunt-connected static generator and/or absorbers whose outputs are varied so as to control specific parameters of the electric power system. The term 'static' is used to indicate that SVCs, unlike synchronous compensators, have no moving or rotating main components. By rapidly controlling the voltage and reactive power, an SVC can contribute to the enhancement of the power system dynamic performance. Normally, voltage regulation is the primary mode of control, and this improves voltage stability and transient stability. However, the contribution of an SVC to the damping of the system oscillation resulting from voltage regulation alone is usually small; supplementary control is necessary to achieve significant damping.[2]The effectiveness of an SVC in enhancing system stability depends on location of the SVC.).

A commonly used topology of a svc shown in fig.(2).Comprises a parallel combination of TCR and fixed capacitor.it is basically a shunt connected static var generator/absorber. Whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific parameters of electrical power system, typically bus voltage.

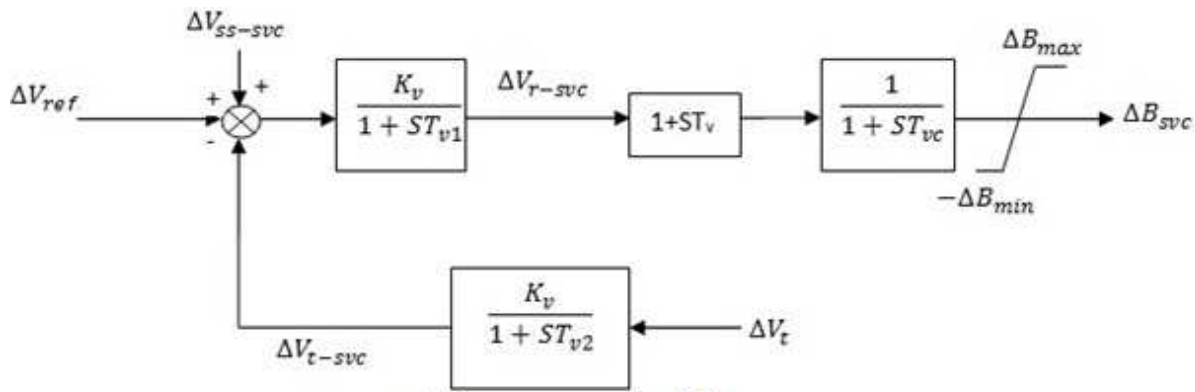


The reactive power injection of a SVC connected to bus k is given by

$$Q_k = V_k^2 B_{SVC}$$

$B_{SVC} = B_C - B_L$; the symbol B_C and B_L are the respective susceptance of the fixed capacitor and TCR.it is also important to note that a svc does not exchange real power with the system.

The small signal dynamic model of a SVC is shown in fig.(3). ΔB_{SVC} is defined as $\Delta B_C - \Delta B_L$.the differential equation from this block diagram can easily be defined as



Fig(3) SVC Dynamic model

$$\begin{aligned} \frac{d}{dt} \Delta B_{svc} &= \frac{1}{T_{svc}} \left\{ -\Delta B_{svc} + \left(1 - \frac{T_{v1}}{T_{v2}} \right) \Delta V_{r-svc} - \frac{K_v T_{v1}}{T_{v2}} \Delta V_{t-svc} \right\} + \frac{K_v T_{v1}}{T_{v2} T_{svc}} \{ \Delta V_{ss-svc} + \Delta V_{ref} \} \\ \frac{d}{dt} \Delta V_{r-svc} &= \frac{1}{T_{v2}} \left\{ -\Delta V_{r-svc} - K_v \Delta V_{t-svc} + K_v V_{ref} + K_v V_{ss-svc} \right\} \\ \frac{d}{dt} \Delta V_{t-svc} &= \frac{1}{T_m} \{ \Delta V_t - \Delta V_{t-svc} \} \end{aligned}$$

K_v, T_{v1}, T_{v2} are the gain and time constant of voltage controller respectively. T_{svc} is the time constant associated with SVC response. T_m is the voltage sensing circuit time constant. Svc control model which has been used is shown above in fig.(3). An SVC comprising a fixed capacitor and a thyristor-controlled reactor is considered for enhancement of the system stability

Power system Stabilizer-

The basic of a power system stabilizer (PSS) is to add damping to the generator oscillation by using auxiliary stabilizing signal(s). To provide damping, the stabilizer must produce a component of electrical torque in phase with the rotor speed variation. This is achieved by modulating the generator excitation so as to develop a component of electrical torque in phase with rotor speed deviation. Shaft speed, integral of power and terminal frequency are among the commonly used input signals to PSS.[3]. PSS based on shaft speed signal has been used successfully since the mid-1960s. a technique developed to derive a stabilizing signal from measurement of shaft speed of a system. Among the important consideration in the design of equipment for the measurement of speed deviation is the minimization of noise caused by shaft run out and other causes.[3-4] the allowable level of noise is dependent on its frequency. For noise frequency below 5Hz, the level must be less than 0.02%, since significant changes in terminal voltage can be produced by low-frequency changes in the field voltage. The application of shaft speed stabilizer to thermal unit requires a careful consideration of the effects on torsional oscillation. The stabilizer, while damping the rotor oscillation, can cause instability of the torsional modes. One approach successfully used to circumvent the problem is to sense the speed at a location on the shaft near the nodes of the critical torsional modes [5-6]. In addition, an electronic filter is used in stabilizing path to attenuate the torsional components.

Power system stabilizer which has been used in this research is shown below in fig.(4).

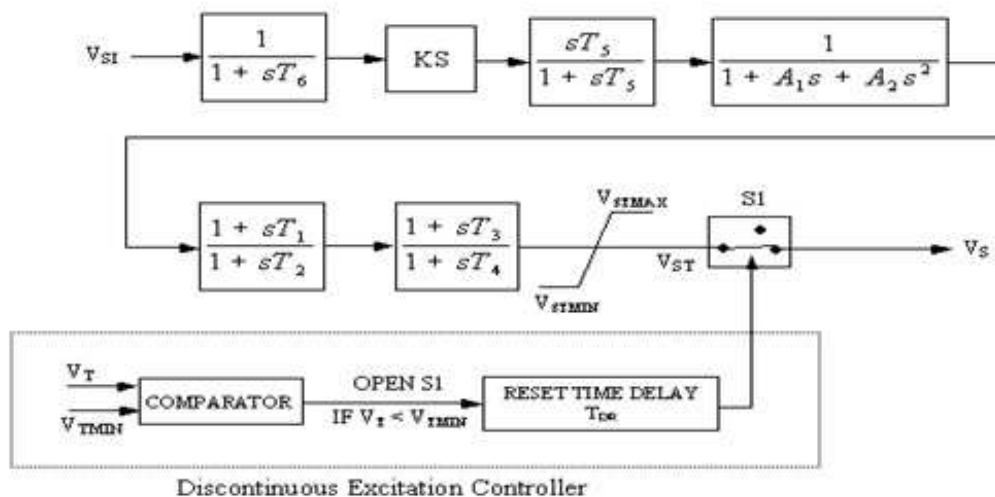


Fig.-(4) IEEE Type-1 PSS(PSS1A)

Exciter-

The IEEE type of DC1 exciter is field-controlled dc commutator exciters, with continuously acting voltage regulators. The exciter may be separately excited or self excited, the latter type being more common. When self-excited, K_e is selected so that initially $V_r = 0$, representing operator action of tracking the voltage regulator by periodically trimming the shunt field rheostat set point.[7]

Test System:-

The test system that has been considered here is the 9-Bus Multi-Machine System as shown below in Fig.(5).

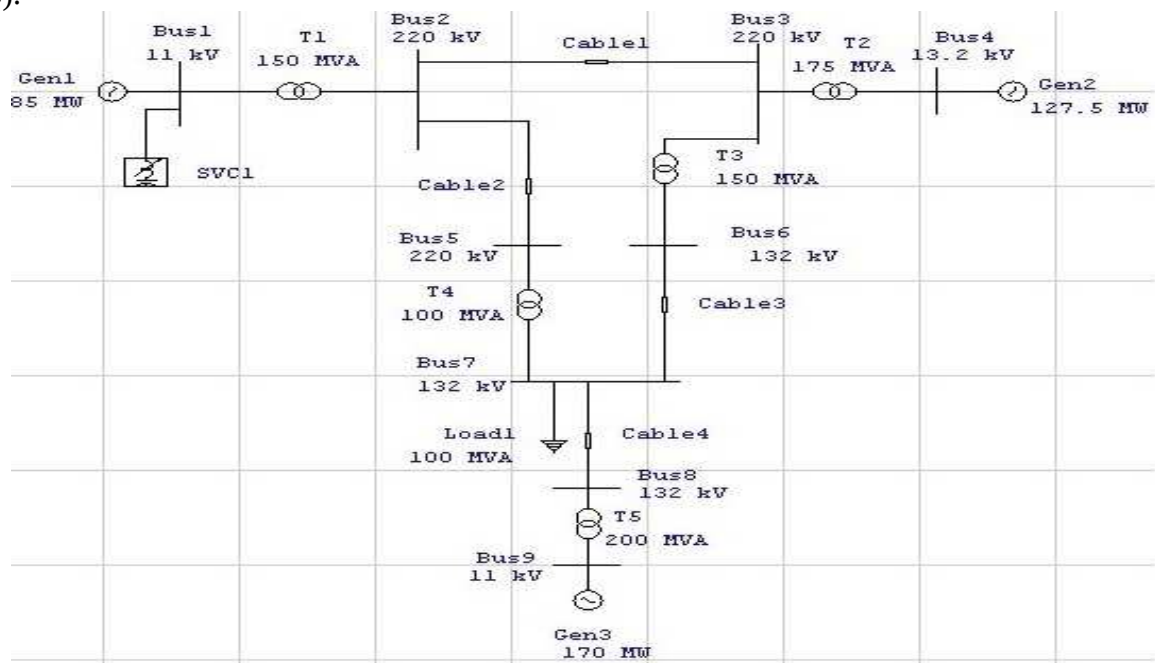


Fig.(5) Test system

Which consisted 9-bus, three generators, four cables, five transformer and one static load of 100 MVA. Gen-1, Gen-2 and Gen-3 rated of 85 MW, 127.5 MW and 170 MW respectively. All other

input parameters of generators are shown below in Table-1,2 and 3.

Table-1 SYNCHRONOUS MACHINE PARAMETERS															
Machine			Rating		Positive sequence impedance(%)								Zero seq. Z(%)		
ID	TYPE	MODEL	MVA	KV	R _a	X _d ''	X _d '	X _d	X _q ''	X _q '	X _q	X ₁	X/R	R ₀	X ₀
Gen1	Generator	Subtransient, Round-Rotor	100	11	1	19	28	155	19	65	155	15	7	1	7
Gen2	Generator	Subtransient, Round-Rotor	150	13.2	1	19	28	155	19	65	155	15	7	1	7
Gen3	Generator	Subtransient, Round-Rotor	200	11	1	19	28	155	19	65	155	15	7	1	7

TABLE-2 DYNAMIC PPARAMETERS OF SYNCHRONOUS MACHINE													
Machine	Connected bus	Time cons.(sec.)				H(Sec.),D(MW pu/Hz)&Saturation					Grounding		
ID	ID	T _{do} ''	T _{do} '	T _{qo} ''	T _{qo} '	H	%D	S100	S120	Sbreak	Conn.	Type	
Gen1	Bus1	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID	
Gen2	Bus4	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID	
Gen3	Bus9	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID	

TABLE-3 MECHANICAL PARAMETERS OF SYNCHRONOUS MACHINE													
Machine		Generator/Motor			Coupling			Prime Mover/Load			Equivalent Total		
ID	TYPE	WR ²	RPM	H	WR ²	RPM	H	WR ²	RPM	H	WR ²	RPM	H
Gen1	Gen.	32406	1500	4	32406	1500	4	32406	1500	4	97217.99	1500	12
Gen2	Gen.	48609	1500	4	48609	1500	4	48609	1500	4	145826.98	1500	12
Gen3	Gen.	64811	1500	4	64811	1500	4	64811	1500	4	194432.98	1500	12

WR²: kg-m² H: MW-Sec/MVA

The IEEE type of DC1 exciter, with continuously acting voltage regulators is installed with all generators. The exciter is self-excited. When self-excited, Ke is selected so that initially Vr =0, representing operator action of tracking the voltage regulator by periodically trimming the shunt field rheostat set point. Input data of exciter is shown below in Table-4.

TABLE-4 POWER SYSTEM STABILIZER (PSS) INPUT DATA														Type: PSS1A
Generator ID	VSI	KS	VSTMax	VSTMin	VTMin	TDR	A1	A2	T1	T2	T3	T4	T5	T6
Gen1	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1
Gen2	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1
Gen3	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1

An IEEE type of PSS1A is connected with all generators. The parameter of power system stabilizer is shown in Table-5.

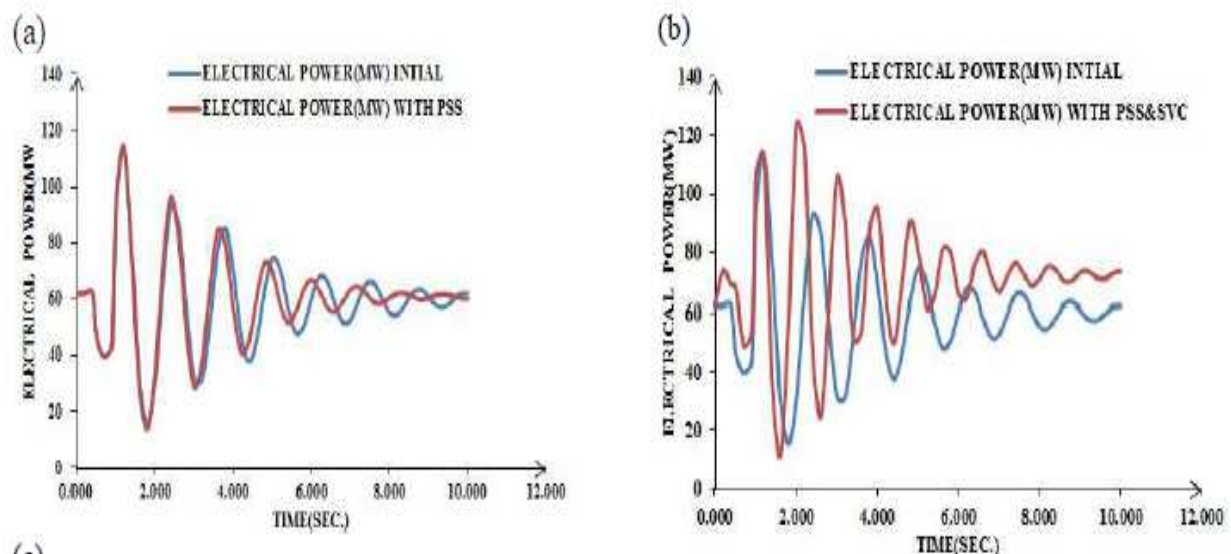
TABLE-5 EXCITER INPUT DATA														Type: DC1
Machine ID	Control Bus ID	KA Efd _{max}	KE	KF	TA	TB	TC	TE	TF	TR	VR _{max}	VR _{min}	SE _{max}	SE.75
Gen1	Bus1	46 2.63	0.05	0.1	0.06	0	0	0.46	1	0.005	1	-0.9	0.33	0.1
Gen2	Bus4	46 2.63	0.05	0.1	0.06	0	0	0.46	1	0.005	1	-0.9	0.33	0.1
Gen3	Bus9	46 2.63	0.05	0.1	0.06	0	0	0.46	1	0.005	1	-0.9	0.33	0.1

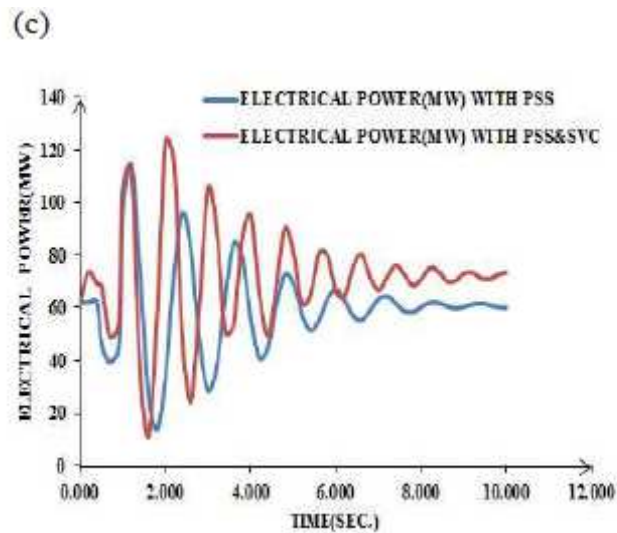
The rating of the SVC is assumed to be 200 Mvar capacitive and 200 Mvar inductive .The voltage regulator gain is set at 10 to provide a 10% slope in the control range.

RESULT&DISCUSSION-

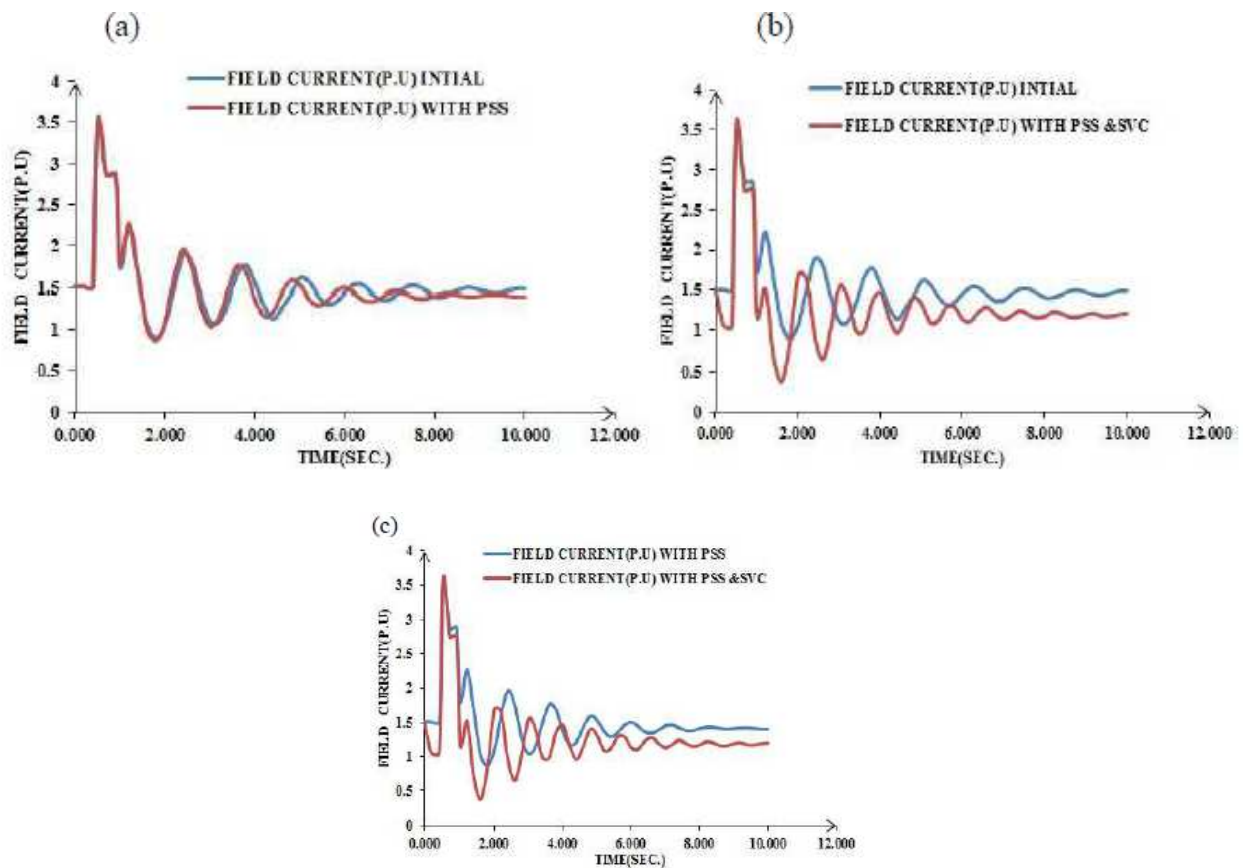
In this paper we discuss the transient stability performance with PSS and SVC.The transient stability improvement is not only sufficient by using one method.so here we use these two combined method for improving stability. Here we use NEWTON RAPHSON METHOD for initial load flow calculation. In which number of iteration is 4 and Solution Precision for the Initial LF is 0.0001 And Time Increment for Integration Steps (Δt) is 0.0100.The effectiveness of an SVC in enhancing system stability depends on location of the SVC.To determine a suitable location for SVC, where the voltage swing are greatest without the SVC. From the initial load flow solution observed that greatest voltage swing on bus-1.so SVC is installed on bus-1. when we used PSS with given data with test system then the electromechanical oscillation for generator electrical power is reduced as well as the steady state power is also enhanced as seen in fig-(6).oscillation in field current and terminal current is also reduced and the magnitude of field current has been also reduced as seen in fig(7) and fig(8). In this work also we observed that Field voltage has been also within limit.

The different plot for generator 1 When fault on bus-7 at 0.5 sec and cleared at 1 sec are shown below in fig(6),fig(7), fig(8)and fig(9).

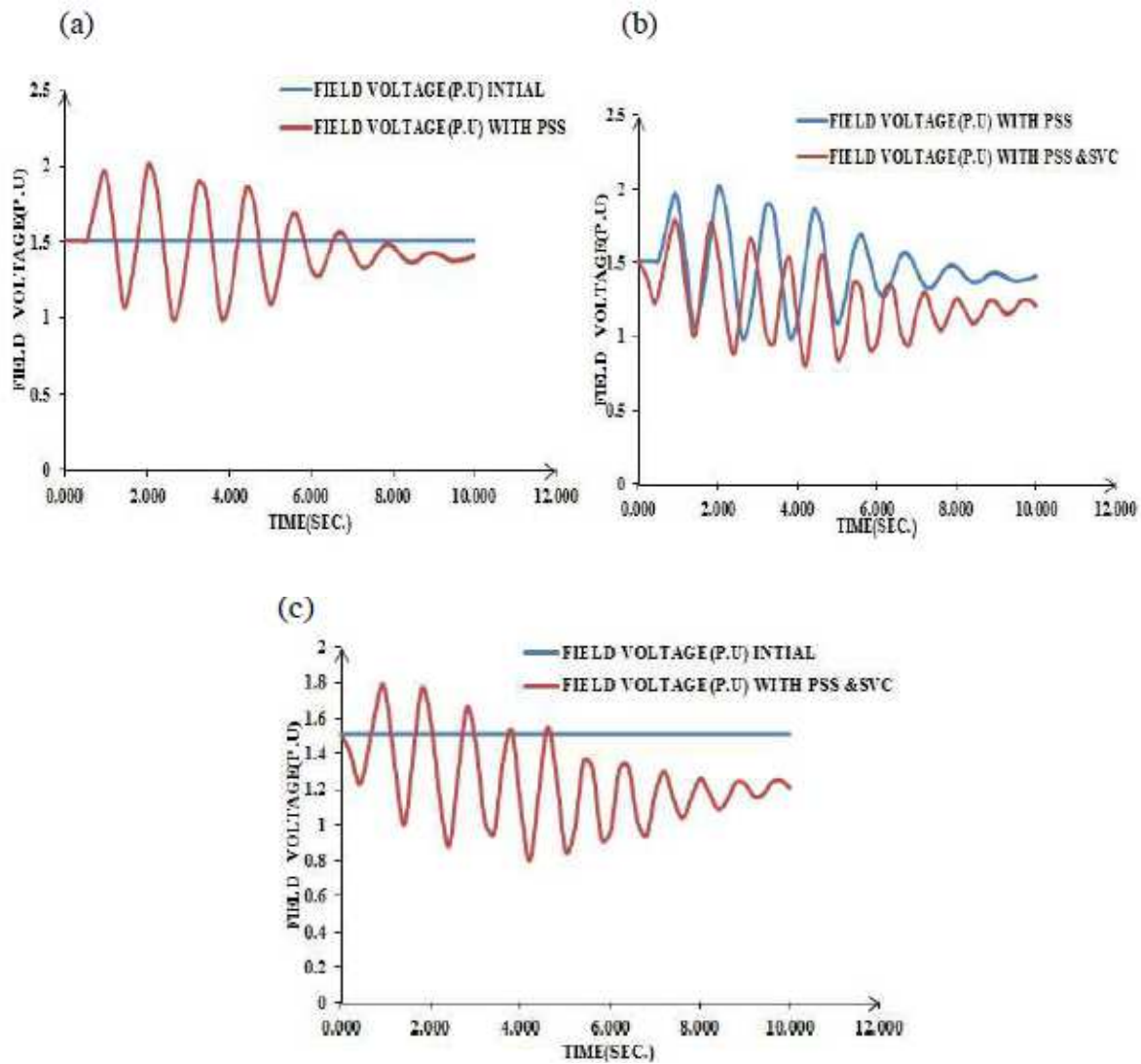




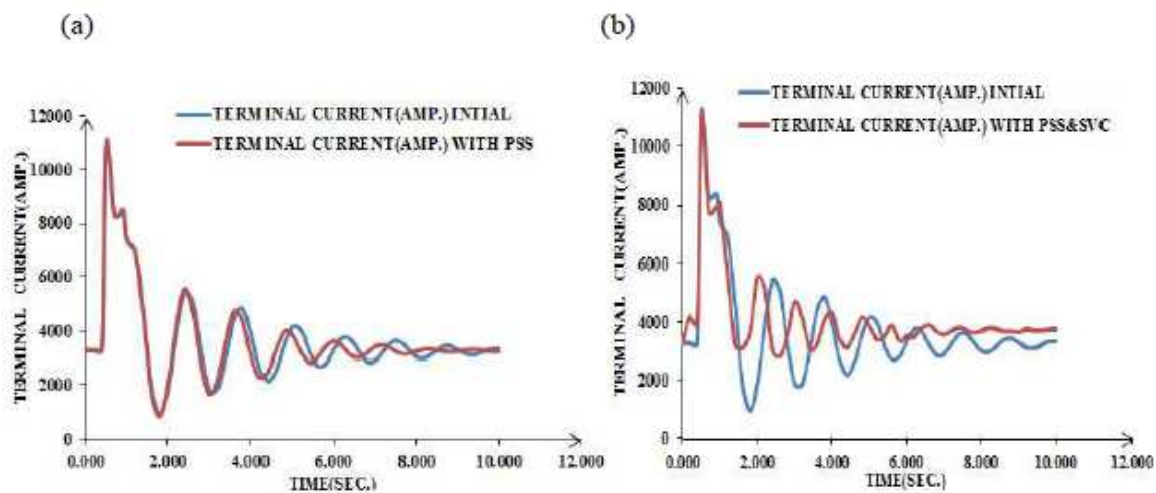
Fig(6) Plot of Electrical power of Gen-1 (a) intial Vs pss (b) intial Vs pss and svc (c) pss Vs pss &svc.

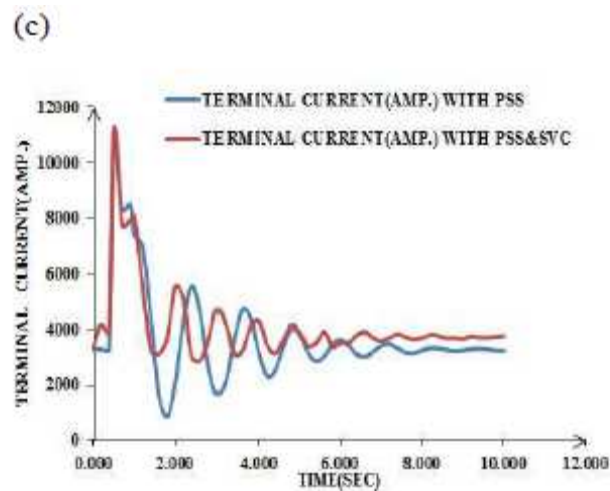


Fig(7)Plot of Field current of Gen-1 (a) intial Vs pss (b) intial Vs pss&svc (c) pss Vs pss &svc.



Fig(8)Plot of Field voltage of Gen-1 (a)intial Vs pss (b)pss Vs ,pss and svc.(c) intial Vs pss&svc





Fig(9)Plot of terminal current of Gen-1 (a) initial Vs pss (b) initial Vs pss&svc (c) pss Vs pss&svc.

CONCLUSION

In this paper a new optimal control approach for PSS and SVC has been Proposed. Transient stability Performances of the multi machine system by using PSS and SVC and conventional method has been compared. And we see that better response in terms of electromechanical oscillation has been achieved in case of with PSS and SVC. The proposed method also has the advantage of considering the permissible system conditions. In general, analytical analysis and simulation results using E-TAP software show that the proposed and good flexibility for transient stability improvement.

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