Comparison of Shunt Facts Devices for the Improvement of Transient Stability of Two Machine Power System using MATLAB Modelling

Arti Devi Patel
Department of Electrical Engineering
Jabalpur Engineering College, Jabalpur, (MP) India

Abstract— This paper presents, the performance of STATCOM placed at midpoint of the two machine power system and compared with the performance of SVC. The comparison of various results found for the different type of faults (single line, double line & three phase fault) occur in long transmission line, and their removal by using shunt FACTS devices is analysed. Computer simulation results under a severe disturbance condition (three phase fault) for different fault clearing times, and different line lengths are analyzed. Both controllers are implemented using MATLAB/SIMULINK. Simulation results shows that the STATCOM with conventional PI controller installed with two machine three bus systems provides better damping oscillation characteristics in rotor angle as compared to two machine power system installed with SVC. The transient stability of two machine system installed with STATCOM has been improved considerably and post settling time of the system after facing disturbance is also improved.

Key words: Transient stability; FACTS devices; SVC, STATCOM; MATLAB/SIMULINK

I. INTRODUCTION

Transient stability is important from the point of view maintaining system security that is the incidence of a fault should not lead to tripping of generating unit due to loss of synchronism and the possibility of a cascaded outage leading to system black out. In recent years, power demand has increased substantially while the expansion of power generation and transmission has been severely limited [1] due to limited resources and environmental restrictions. Transient stability limit depends on the type of disturbance, location and magnitude of disturbance, the type of fault and its location in the system, the time required to clear the fault. Recent development of power electronics introduces the use of FACTS devices in power systems. FACTS devices are capable of controlling the network condition in a very fast manner and this unique feature of FACTS devices can be exploited to improve the transient stability of a system. Reactive power compensation is an important issue in electrical power systems and shunt FACTS devices play an important role in controlling the reactive power flow to the power network and hence the system voltage fluctuations and transient stability [2]. SVC and STATCOM are members of FACTS family that are connected in shunt with the system. Even though the primary purpose of shunt FACTS devices is to support bus voltage by injecting (or absorbing) reactive power, they are also capable of improving the transient stability by increasing (decreasing) the power transfer capability when the machine angle increases (decreases), which is achieved by operating the shunt FACTS devices in capacitive (inductive) mode [3].

Shunt FACTS devices give maximum benefit from their stabilized voltage support when sited at the mid-point of the transmission line [4]. It is observed that STATCOM gives better results for transient stability as compared to SVC.

A. Problem Statement:

The transient stability studies involve the determination of whether or not synchronism is maintained after the machine has been subjected to severe disturbance. This may be sudden application of load, loss of generation, loss of large load, or a fault on the system. In most disturbances, oscillations are of such magnitude that linearization is not permissible and the nonlinear swing equation must be solved. The stability problem is concerned with the behavior of the synchronous machines after they have been perturbed. If the perturbation does not involve any net change in power, the machines should return to their original state. If an unbalance between the supply and demand is created by a change in load, in generation, or in network conditions, a new operating state is necessary. In any case all interconnected synchronous machines should remain in synchronism if the system is stable; i.e., they should all remain operating in parallel and at the same speed. This paper is organized as following the Introduction and problem statement, Section II illustrates the Two-area Power System Model. In section III presents brief details about Shunt FACTS devices such as Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM). Section IV presents the simulation model and result without FACTS devices and with SVC, STATCOM individually when a 3-ph fault occurred between bus bars B1 & B2. Section V presents results of the proposed model.

II. DESIGN OF STUDY MODEL OF POWER SYSTEM

An extended power system can be dividing into a number of load frequency control areas inter connected by means of tie-lines. Without loss of generality we shall consider a two area case connected by a single tie-line as illustrated in fig1. The two machines are equipped with a hydraulic turbine and governor (HTG), excitation system and power system stabilizer (PSS). Both SVC and STATCOM used for this model have the same rating of ±200 MVA and the reference voltage is set to 1 pu for both SVC and STATCOM. A three phase fault occurs at sending end bus at time t = 4.0s, for 0.1sec time duration. The original system is restored upon the clearance of the fault.

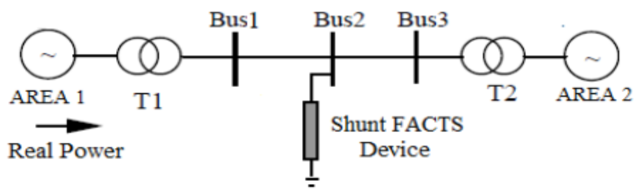

Fig. 1: Two-Area Power System with FACTS Device.

The transient following a system perturbation is oscillatory in nature, but if the system is stable, these oscillations will be damped toward a new quiescent condition. These oscillations however are reflected as fluctuations in the power flow over the transmission lines. If a certain line connecting the two groups of machines undergoes excessive power fluctuations, it may be tripped out by its protective equipment there by disconnecting the two groups of machines. This problem is termed the stability of the tie line, even though in reality it reflects the stability of the two groups of the machines. The shunt converter is able to generate or absorb controllable reactive power in both operating modes (i.e., rectifier and inverter). The independently controlled shunt reactive compensation can be used to maintain the shunt converter terminal AC voltage magnitude at a specified value.

III. SHUNT FACTS DEVICES

FACTS controllers may be based on thyristor devices with no gate turn-off or power devices with gate turn-off capability. FACTS controllers are used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines. The basic principles of the following FACTS controllers, which are used in the two-area power system under study, are discussed briefly [5].

A. Static Var Compensator (SVC)

Static var systems are applied by utilities in transmission applications for several purposes. The primary purpose is usually for rapid control of voltage at weak points in a network. Installations may be at the midpoint of transmission interconnections or at the line ends. Static Var Compensators are shunt connected static generators / absorbers whose outputs are varied so as to control voltage of the electric power systems. In its simple form, SVC is connected as Fixed Capacitor-Thyristor Controlled Reactor (FC-TCR) configuration as shown in Fig. 2(a). The SVC is connected to a coupling transformer that is connected directly to the ac bus whose voltage is to be regulated. The effective reactance of the FC-TCR is varied by firing angle control of the anti-parallel thyristors. The firing angle can be controlled through a PI (Proportional + Integral) controller in such a way that the voltage of the bus, where the SVC is connected, is maintained at the reference value.

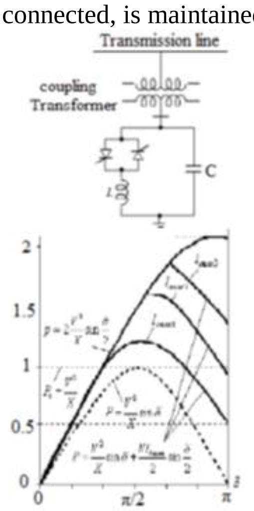

Fig. 2: (a) SVC

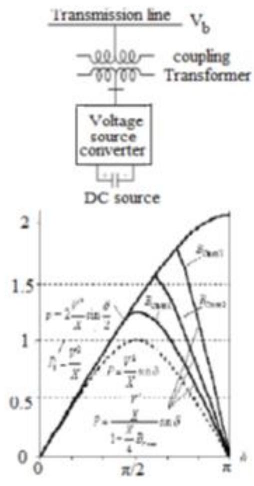

Fig. 2(b): STATCOM

B. Static Synchronous Compensator (STATCOM)

A STATCOM, controlled to regulate the terminal voltage, can increase the transient stability by maintaining the transmission voltage at the midpoint or some appropriate intermediate point in face of the increased power flow encountered immediately after fault clearing. However, the transient stability can be increased further by temporarily increasing the voltage above the regulation reference for the duration of the first acceleration period of the machine. The voltage increased above its nominal value will increase the electric power transmitted and thus will increase also the deceleration of the machine. This is illustrated in fig. 2(b), where the P versus δ plots of a simple two-machine system with different midpoint compensations represents the P versus δ is shown [2, 6]. The plot marked $P = 2V^2\sin(\delta/2)/X$ plot obtained with an ideal compensator holding the midpoint voltage constant. The plots marked with STATCOM and SVC represents these compensators with a given rating insufficient to maintain constant midpoint voltage over the total range of δ. Thus, the P versus δ plots are identical to that of the ideal compensator up to a specific δ ($\delta = \delta i$) at which the SVC becomes a fixed capacitor and the STATCOM a constant current source. In the interval between δi and δ, the P versus δ plots are those which correspond to a fixed midpoint capacitor and a constant reactive current source. The continuations of these plots in the δi to zero interval show the P versus δ characteristic of the two-machine system with the maximum capacitive admittance of the SVC and with the maximum capacitive output current of the STATCOM. That is angles smaller than δi the transmission line is overcompensated and for angles greater, it is undercompensated. This overcompensation capability of the compensator can be exploited to enhance the transient stability by increasing the var output to the maximum value after fault clearing.

IV. SIMULATION MODEL

A 1000 MW hydraulic generation plant1 is connected to a load centre through a long 500 kV,720 km transmission line. The load centre is modeled by a 5000 MW resistive load. The load is fed by the remote 1000 MW plant and a local hydraulic generation plant2 of 5000 MW. In order to maintain system stability after faults, the transmission line is shunt compensated at its centre by a 200-MVAR SVC, and STATCOM respectively (Fig. 3, 4). In fig. 5 system is shown without FACTS devices.

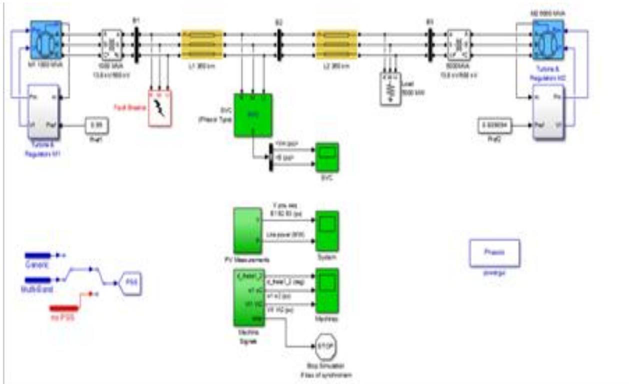
Fig. 3: Two Machine Power System Simulink Model with SVC Controller

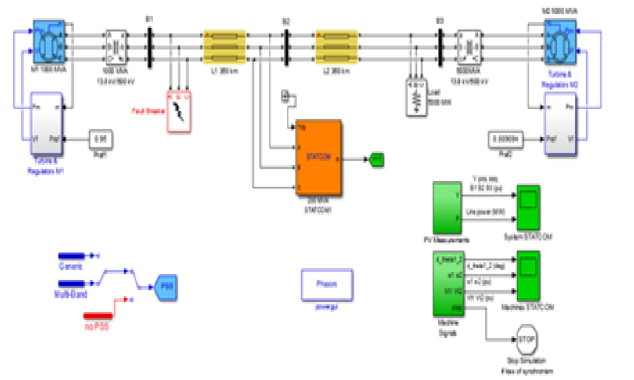

Fig. 4: Two Machine Power System Simulink Model with STATCOM Controller.

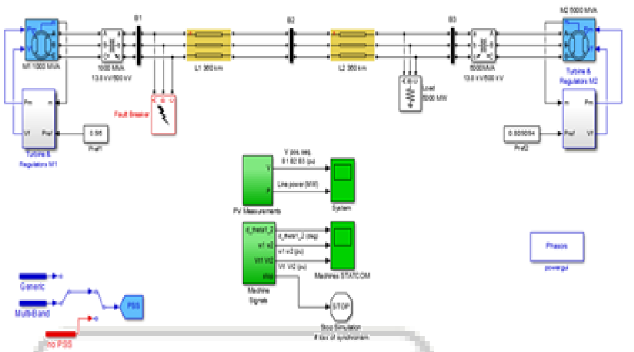

Fig. 5: Two Machine Power System Simulink Model without Shunt FACTS Controller.

A. *Simulation Results with Different Type of Fault:*

By using fault circuit breaker different type of fault is created in the system. When phase A is selected single phase fault occur. Same way phase A, B selected and double line fault occur. By selecting phase, A, B, C, create three phase fault. This is observed that without shunt FACTS devices PSS is able to remove single line-to-ground faults, but in three phase fault condition its failed. Positive sequence voltage, line power, rotor angle difference, speeds, and terminal voltage with three phase fault with respect to time and without FACTS devices shown in fig.6.

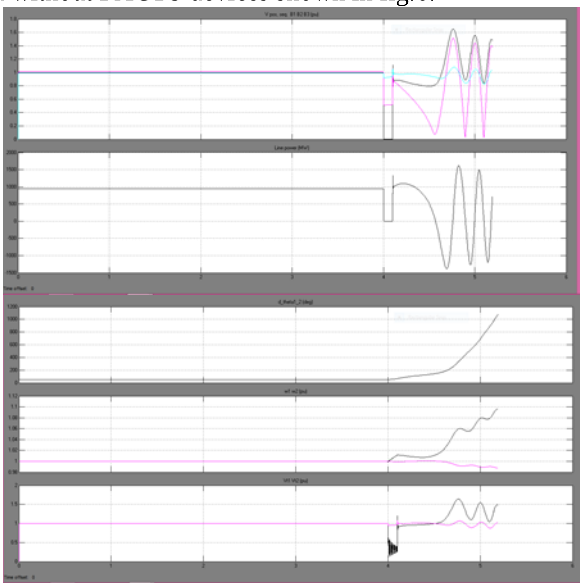

Fig. 6: Three Phase Fault without FACTS Devices.

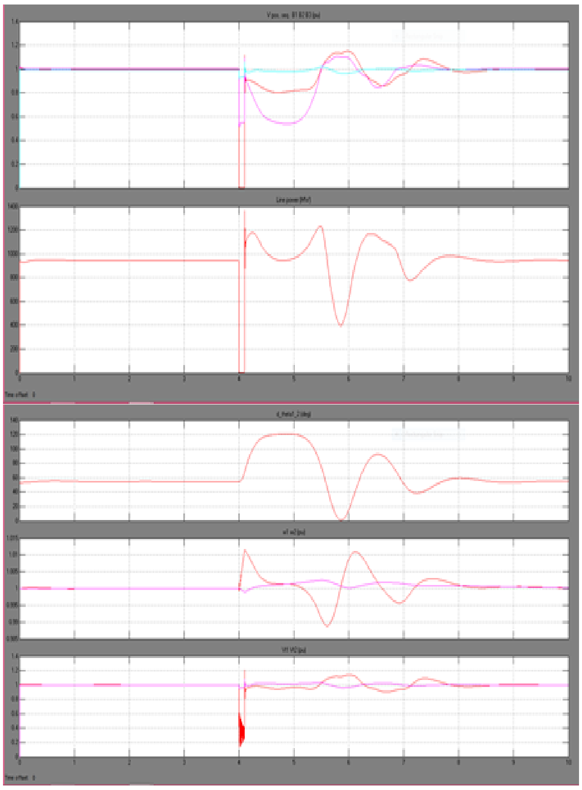

Fig. 7: Three Phase Fault with SVC

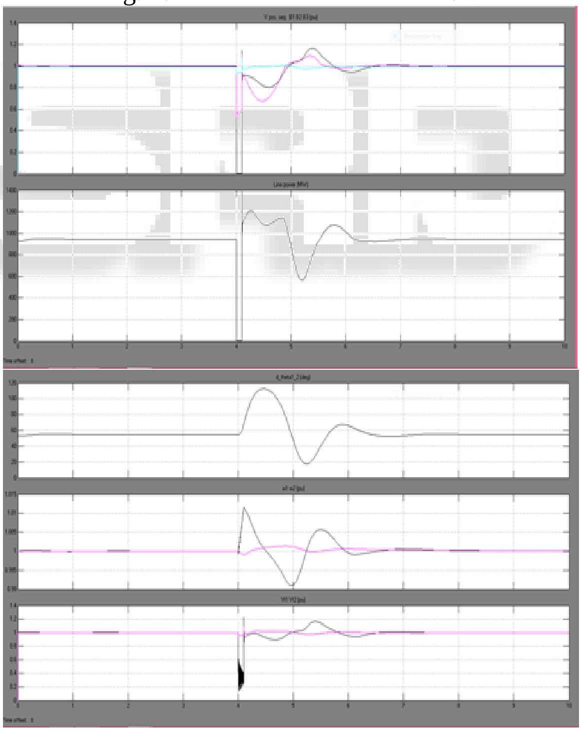

Fig. 8: Three Phase Fault with STATCOM

The system has a SVC/STATCOM installed at B2. It is considered that a 3-phase symmetrical short circuit fault of 0.1seconds occur at bus B1. Put the Multi band type PSS in service by setting the command in PSS block equal to 2. Open the SVC/STATCOM block menu and change the mode of operation to voltage regulation. The system is simulated in Matlab/Simulink environment and graphs of SVC STATCOM are shown in fig-7 and fig-8. From the fig-7 and 8, it is inferred that the oscillations in generator rotor angle is decreased and settling time for the oscillations is found to be 2.8 seconds by using STATCOM. Also, terminal voltages profile has been improved after clearance of fault installed with STATCOM. Hence, the transient stability of two machine system installed with STATCOM has been improved considerably and post settling time of the system after facing disturbance is also improved. It is also observed that both shunt devices responses are approximately same at single line to ground fault and double line fault, but for three phase fault STATCOM performance is better. These results are shown in table-1

	Single line	Double line	Three phase
Without FACTS	2.4 sec	3.6sec	infinite
SVC	1.8sec	2.2sec	3.9sec
STATCOM	1.7sec	2.1sec	2.3sec

Table 1: Post Fault Settling Time with Different Type of Faults of Two Area Power System

V. SIMULATION RESULTS WITH DIFFERENT LINE LENGTH

On placing the SVC/STATCOM in the transmission line at the distance of L1=360km & L2=360km i.e. absolutely at the midpoint of the transmission line, with three phase fault we can get the stabilized waveform at fault clearing time t=0.1 sec only. Shown in fig.7 and 8.

Next we place the STATCOM/SVC at the distance L1=370km & L2=370km and observe the waveform as shown in fig 9 and 10, respectively. From the waveforms we can say that by placing STATCOM at this length system is stable at 3.7 sec but in case of SVC system become unstable.

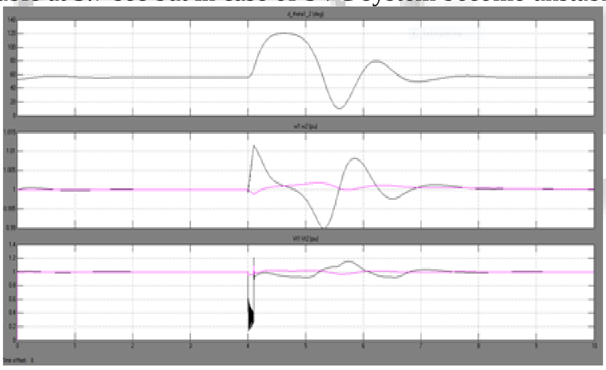

Fig. 9: STATCOM with Three Phase Fault at 740km Length

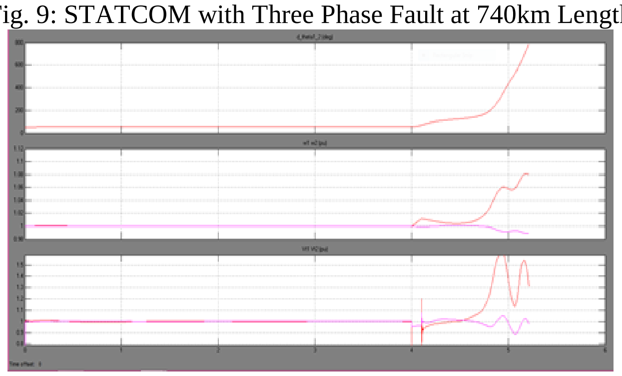

Fig. 10: SVC with Three Phase Fault at 740 Km Length

When we increase the line length L1=380km, L2=380km and place the STATCOM in middle of the line then the results are shown in fig11. At this length both devices give unstable results. By observing table-2 we conclude that STATCOM performance is better for longer line length as compared to SVC.

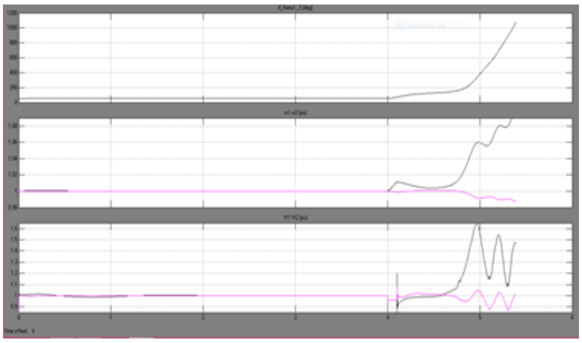

Fig. 10: STATCOM with Three Phase Fault at 760 Km Length.

Transmission line length(km)	SVC [Rotor angle difference (degree)], settling time	STATCOM [Rotor angle difference (degree)], settling time
L1=350,L2=350	110 , 2.3sec stable	108, 2.2sec stable
L1=360,L2=360	121, 3.7sec stable	112, 2.3sec stable
L1=370,L2=370	1080, unstable	120, 3.7sec
L1=380,L2=380	1080, unstable	1080, unstable

Table 2: Comparison of SVC and STATCOM at Different Line Length.

VI. CONCLUSION

In this paper dynamics of the power system is compared with and without the presence of FACTS devices and Power system stabilizers in the event of major disturbances. The performance of one of the FACT device i.e. STATCOM for transient stability enhancement is compared with the performance of other FACT device i.e. SVC. Proposed FACTS controllers were implemented in MATLAB/ SIMULINK. Simulation results indicate that the STATCOM controller installed with two machine systems provides better damping characteristics in rotor angle as compared to two machine system installed with SVC. Also, the post settling time of the two machine system installed with STATCOM is found to be less i.e. near to 2.3sec than the system with SVC 3.7 sec. Thus, transient stability enhancement of the two machine system installed with STATCOM is better than that installed with SVC.

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