Comparative Study on the Effectiveness of Shunt Facts Devices (SVC, STATCOM) and Series Facts Device (TCSC) for the Enhancement of Transient Stability of Two Area Multi Machine Power System

Md. Shakil Haque*, Md. Tariqur Rahman, Md. Rezaul Karim, Md. Mahbubur Rahman
Department of EEE,
University of Dhaka (Mymensingh Engineering College)
Mymensingh, Bangladesh

***Abstract*—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. FACTS devices are capable of controlling the network condition in a very fast manner by reactive power management and can be exploited to improve the transient stability of a system. The purpose of this paper is to deal with the comparative performance of SVC, STATCOM and TCSC for the transient stability improvement of two area multi machine power system. Simulations are carried out in MATLAB/SIMULINK environment for two area multi machine system modeling with shunt and series FACTS devices to analyze the transient stability improvement of the system. Among the shunt controllers, the STATCOM performs better than SVC. But the TCSC is more effective than the shunt controllers, as it offers greater controllability of the power flow in the line and also increases the transfer limits or to improve the transient stability.**

Keywords—Transient stability; FACTS devices; SVC; STATCOM; TCSC; MATLAB/SIMULINK.

I. INTRODUCTION

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. Now, more than ever, advanced technologies are vital for the reliable and secure operation of power systems. Better utilization of the existing power system is provided through the application of advanced control technologies recent development of power electronics introduces the employ of FACTS controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be oppressed to improve the voltage stability, and steady state and transient stabilities of a complex power system [2]. The availability of Flexible AC Transmission System (FACTS) controllers [3], such as Static Var Compensators (SVC), Thyristor Control Series Compensators (TCSC), Static Synchronous Compensators (STATCOM), and Unified Power Flow Controller (UPFC), has led their use to damp inter-area oscillations. SVC is a first generation FACTS device that is used to maintain the voltage at a particular bus by means of reactive power compensation. SVC is also used to dampen power swings, improve transient stability, and reduce system losses by optimized reactive power control [4]-[5]. STATCOM is a power electronic based device that has capability of controlling the power flow through the line by injecting appropriate reactive power to power system. Amongst the available FACTS [6] devices for transient stability enhancement, the TCSC is the most versatile one. The TCSC controller can be designed to control the power flow, to increase the transfer limits or to improve the transient stability. This paper aims to explain the improvement of transient stability of a two-area power system with a TCSC. A Matlab/Simulink model is developed for a two-area power system with a TCSC. The performance of TCSC is compared with other FACTS devices such as SVC and STATCOM respectively. From the simulation results, it is inferred that TCSC is an effective FACTS device for transient stability improvement.

II. THEORY

A. Static Var Compensator (SVC):

Static var compensator are shunt connected fact device whose output are varied to control the voltage of the electric power system by generating or absorbing reactive power. The SVC uses conventional thyristors to achieve fast control of shunt-connected capacitors and reactors. The configuration of the SVC is shown in Fig. 1.

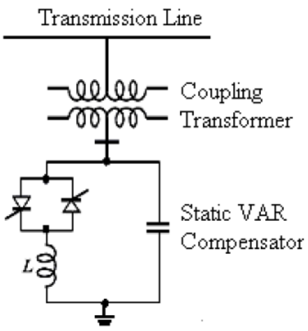

Fig. 1. Schematic Diagram of SVC.

B. Static Synchronous Compensator (STATCOM):

In the transmission systems, STATCOM provides voltage support to buses by modulating bus voltages during dynamic disturbances in order to provide better transient characteristics, improve the transient stability margins and to damp out the system oscillations due to these disturbances.

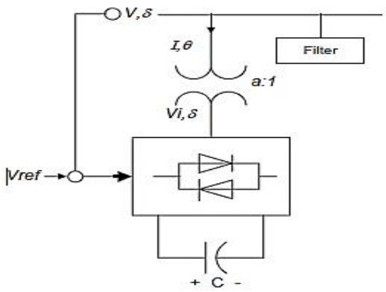

Fig. 2. Schematic Diagram of STATCOM.

C. Thyristor Controlled Series Capacitor (TCSC) :

TCSC is the series FACTS devices which consists of the capacitor bank reactor bank and thyristor. The thyristors control the reactance that dictates the power flow through a line. The TCSC can be applied to improve transient stability of power system.

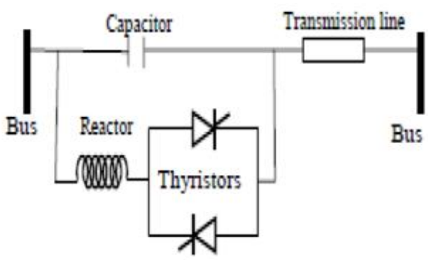

Fig. 3. Schematic Diagram of TCSC between two buses.

A TCSC is a series-controlled capacitive reactance that can provide continuous control of the power of the AC line over a wide range. A simple understanding of TCSC functioning can be obtained by analyzing the behavior of a variable inductor connected in parallel with an FC, as shown in Fig. 4.

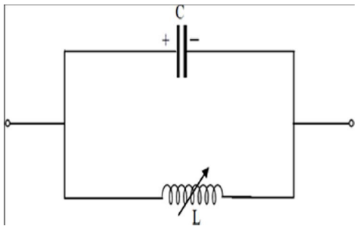

Fig. 4. A variable Inductor in Shunt with a FC.

The equivalent impedance, Zeq, of this LC combination is expressed below. The impedance of the FC alone, however, is given by There are essentially three modes of TCSC operation.

$$Z_{eq} = -j \frac{1}{\omega c - \frac{1}{\omega L}}$$

The impedance of the FC alone, however, is given by $-j[\frac{1}{\omega c}]$.

The impedance characteristics curve of a TCSC device is drawn between effective reactance of TCSC and firing angle α [7, 8, 9, 10]

The net reactance of TCR, X_L (α) is varied from its minimum value X_L to maximum value infinity. Likewise effective resistance of TCSC starts increasing from TCR X_L value to till the occurrence of parallel resonance condition X_L (α) $=X_C$. This region is inductive region. Further increasing of X_L (α) gives capacitive region, Starts decreasing from the infinity point of minimum value of capacitive reactance XC. Thus, impedance characteristics of TCSC shows, both capacitive and inductive region are possible though varying firing angle (α).

From 90 < α <$\alpha_L$lim Inductive region.

α_L lim< α < $\alpha_C$lim Capacitive region

Between $\alpha_L$lim < α < $\alpha_C$lim Resonance region. While selecting inductance, X_L should be sufficiently smaller than that of the capacitorX_C. Since getting both effective inductive and capacitive reactance across the device. Suppose if X_C is smaller than the X_L, then the only capacitive region is possible in impedance characteristics. In any shunt network, the effective value of resistance follows the lesser resistance present in the branch. So only one capacitive reactance region will appears. Also $X_L$should not be equal to X_C or else a resonance develops that result in infinite impedance; an unacceptable condition.

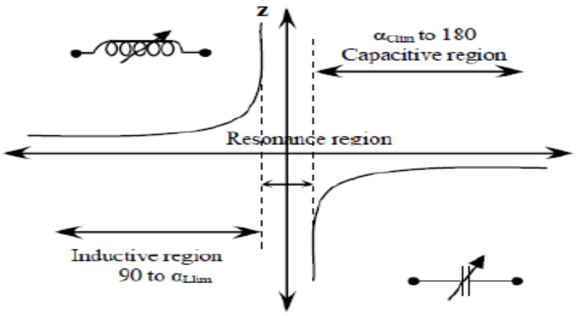

Fig. 5. Impedance versus firing Characteristic curve.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 02, February-2015

III. MODELING OF THE SYSTEM

Two single line diagram for Shunt and Series FACTS devices represent a simple 500 kV transmission system are shown in Fig. 6 and 7.

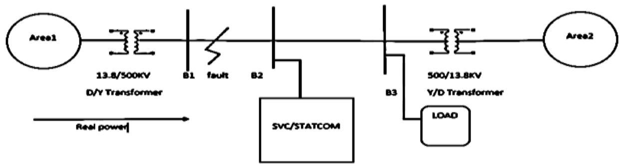

Fig. 6. Two area power system with Shunt (SVC, STATCOM) FACTS devices.

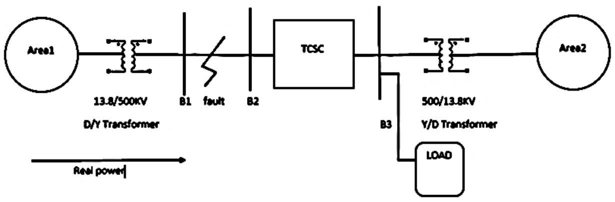

Fig. 7. Two area power system with Series (TCSC) FACTS devices.

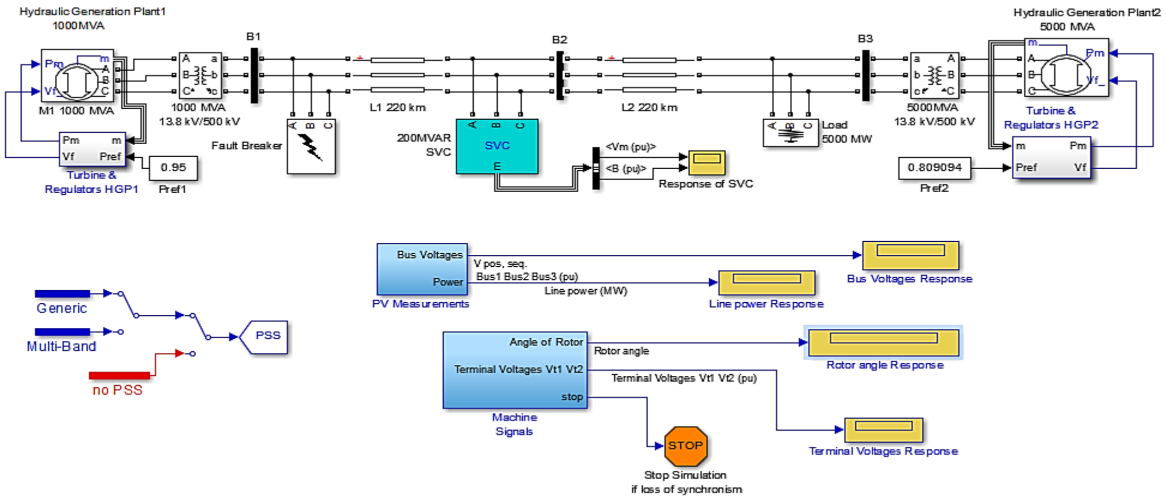

Fig. 8. Complete Simulink model of multi machine power system with SVC.

A 1000 MW hydraulic generation plant1 is connected to a load centre through a long 500 kV, 440 km transmission line. The load centre is modelled 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 or series compensated at its centreby a 200-MVAR SVC, STATCOM or TCSC respectively (Fig. 8, 9, 10). The two machines are equipped with a Hydraulic Turbine and Governor (HTG), Excitation system and Power System Stabilizer (PSS). Any disturbances that occur in power systems due to line faults (considered 1-phase fault) can result in inducing electromechanical oscillations of the electrical generators.

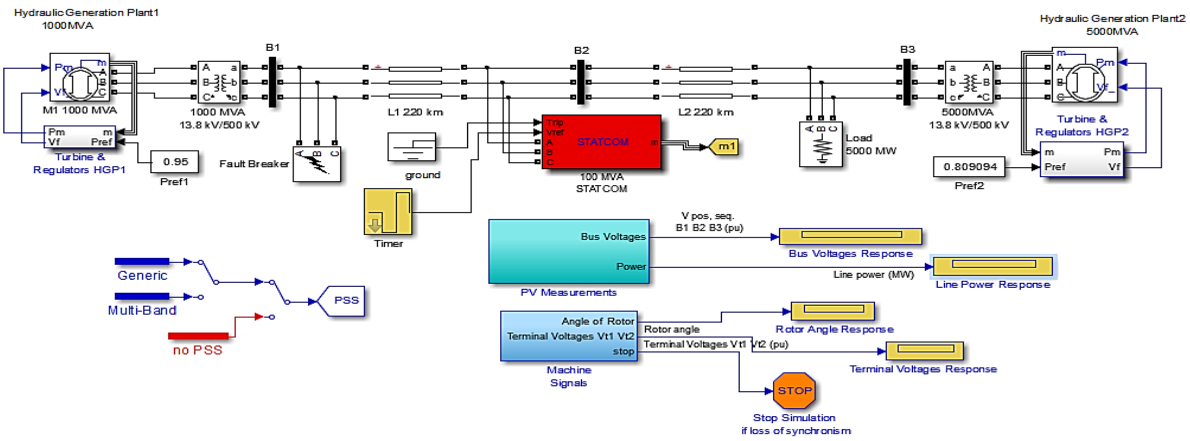

Fig. 9. Complete Simulink model of multi machine power system with STATCOM.

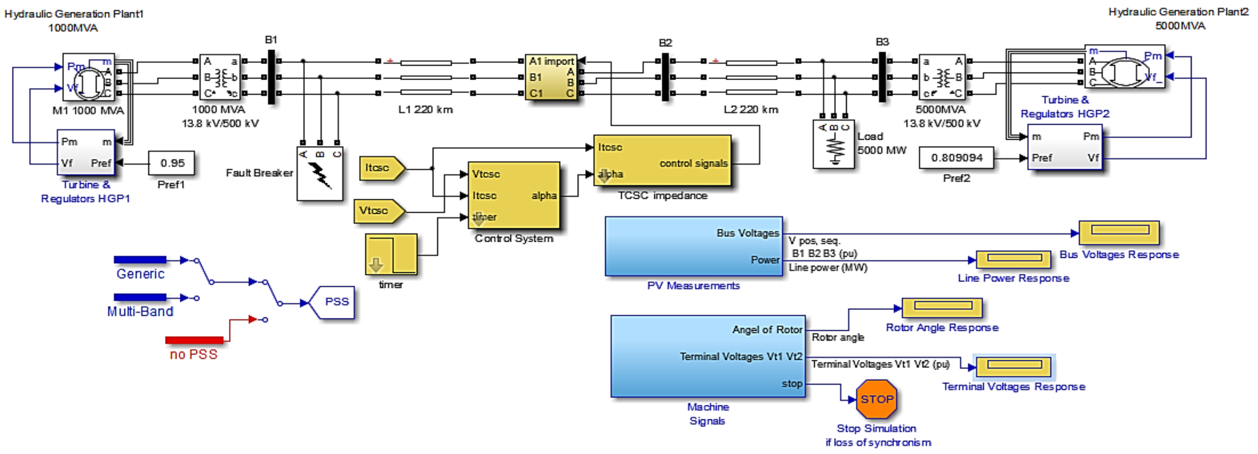

Fig. 10. Complete Simulink model of multi machine power system with TCSC

A 1000 MW hydraulic generation plant1 is connected to a load centre through a long 500 kV, 440 km transmission line. The load centre is modelled 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 or series compensated at its centre by a 200-MVAR SVC, STATCOM or TCSC respectively (Fig. 8, 9, 10). The two machines are equipped with a Hydraulic Turbine and Governor (HTG), Excitation system and Power System Stabilizer (PSS). Any disturbances that occur in power systems due to line faults (considered 1-phase fault) can result in inducing electromechanical oscillations of the electrical generators.

IV. Simulation Reasult

A. Simulation results with SVC:

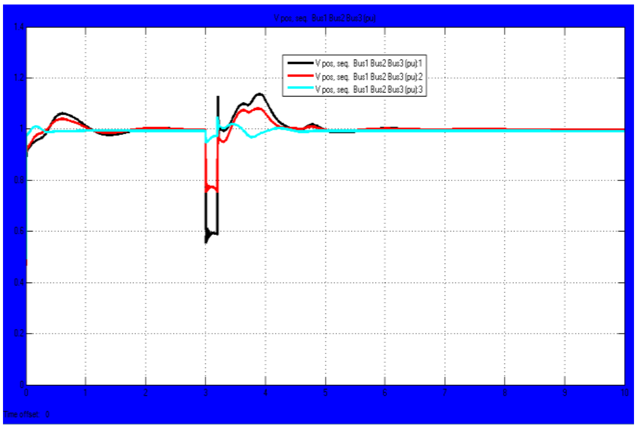

Fig. 11(a). Bus Voltages B1, B2, B3 with SVC and PSS.

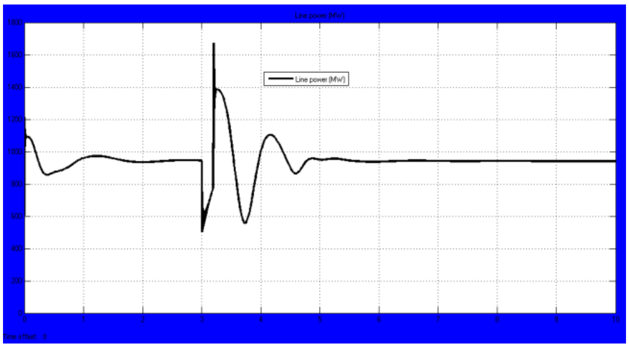

Fig. 11(b). Line Power with SVC and PSS.

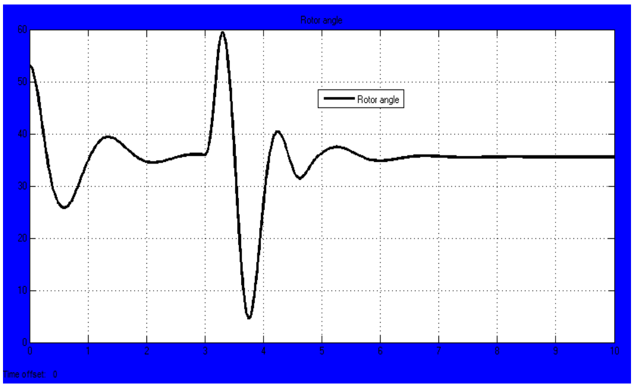

Fig. 11(c). Rotor Angle Deviation with SVC and PSS.

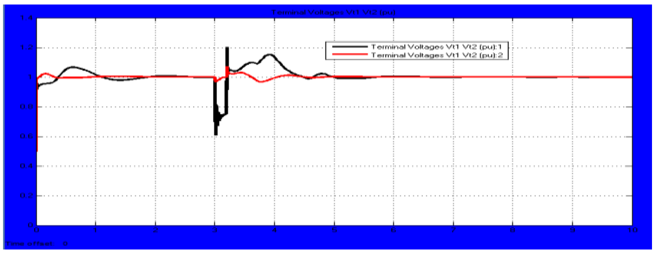

Fig. 11(d). Terminal Voltages V_{t1}, V_{t2} with SVC and PSS.

When a 1-phase fault was occurred at 3.0s & circuit breaker was opened at 3.2s (4-cycle fault), With SVC, the system voltages and line power become stable within 7.5s [Fig.11 (a, b)] and machines rotor angle deviation becomes stable within 7.3s Fig. 11(c).Terminal voltages response curve is also shown in Fig. 11(d).

B. Simulation results with STATCOM:

When a 1-phase fault was occurred at 3.0s & circuit breaker was opened at 3.2s (4-cycle fault), with STATCOM, the system voltages and line power become stable within 6.5s [Fig. 12(a, b)] and machines rotor angle deviation becomes stable within 7s Fig. 12(c). Terminal voltages response curve is also shown in Fig. 12(d).

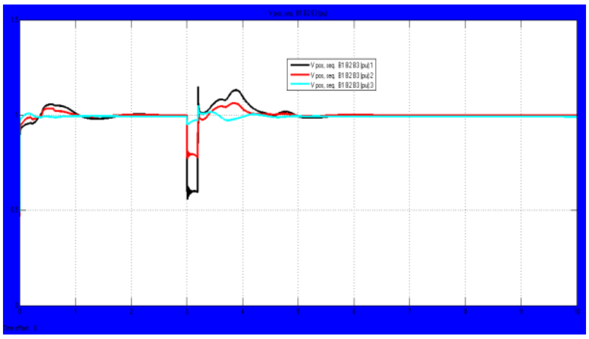

Fig. 12(a). Bus Voltages B1, B2, B3 with STATCOM and PSS.

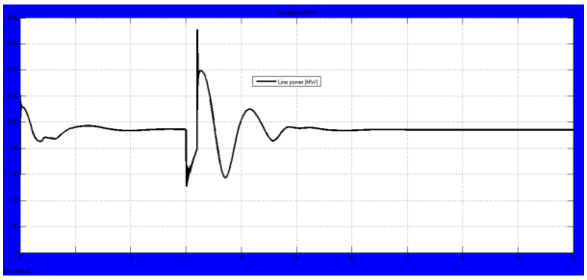

Fig. 12(b). Line Power with STATCOM and PSS.

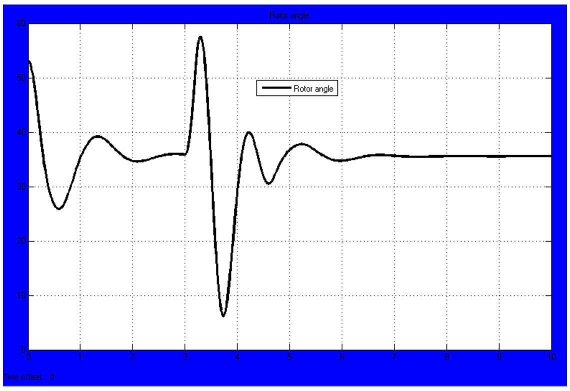

Fig. 12(c). Rotor Angle Deviation with STATCOM and PSS.

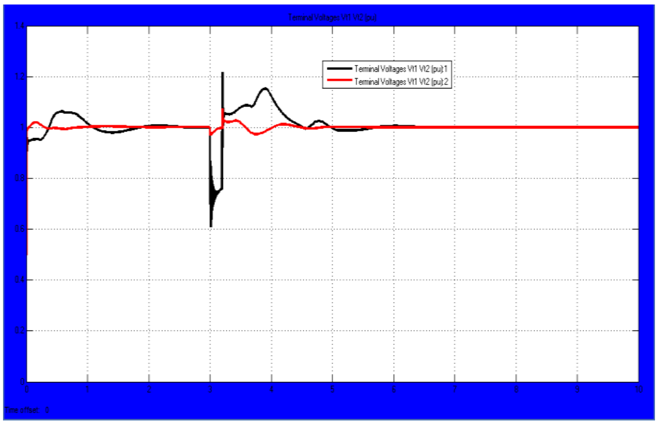

Fig. 12(d). Terminal Voltages V_{t1},V_{t2} with STATCOM and PSS.

C. Simulation results with TCSC:

A complete Simulink model of two machine power system with TCSC is shown in Fig. 13. When a 1-phase fault was occurred at 3.0s & circuit breaker was opened at 3.2s (4 cycle fault), with TCSC, the system voltages and line power become stable within 7s Fig. 13(a, b) and machines rotor angle deviation become stable within 6.5s Fig. 13(c).Terminal voltages response curve is also shown in Fig. 13(d).

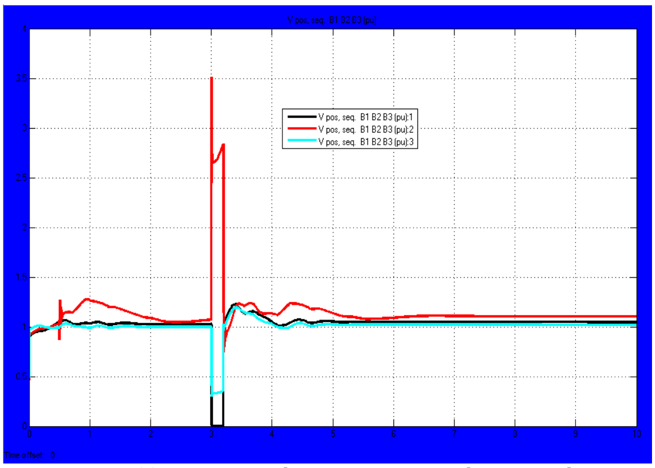

Fig. 13(a). Bus Voltages B1, B2, B3 with TCSC and PSS.

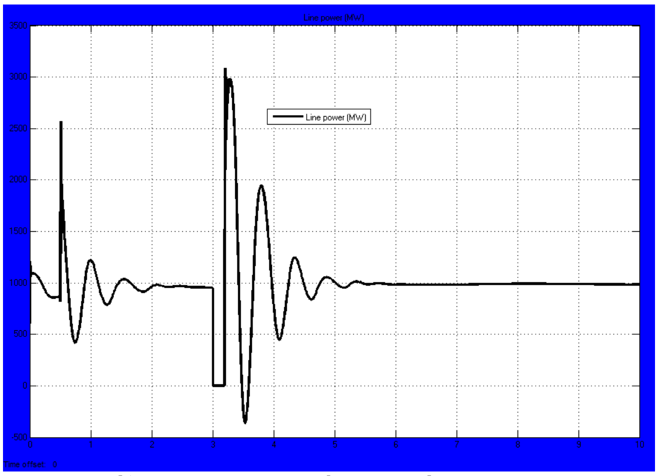

Fig. 13(b). Line Power with TCSC and PSS.

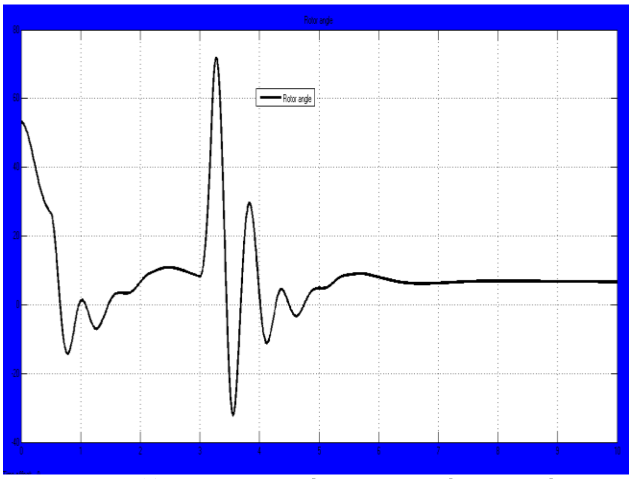

Fig. 13(c). Rotor Angle Deviation with TCSC and PSS.

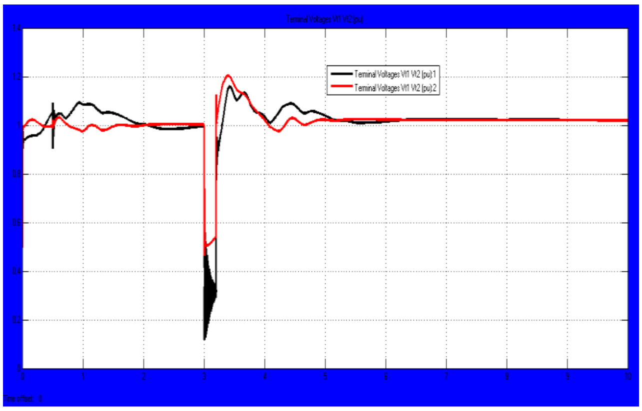

Fig. 13(d). Terminal Voltages V_{t1}, V_{t2} with TCSC and PSS.

TABLE I. Comparison between SVC, STATCOM and TCSC Devices; 1-Phase Fault (Stability Time in sec).

FACTS Device	Bus Voltages	Power	Rotor Angle Deviation
No FACTS Device	infinity	infinity	infinity
SVC	7.5s	7.5s	7.5s
STATCOM	6.5s	6.5s	7s
TCSC	7s	7s	6.5

From the above Table I. it is decided in Table II. that,

TABLE II. Decision of stability.

FACTS Device	Power System Stability	Transient Stability	Settling time
SVC	Yes	Low	6.5
STATCOM	Yes	Medium	5.5
TCSC	Yes	High	4.5

V. RESULTS DISCUSSIONS

From TABLE I and TABLE II, It is investigated that the series FACTS device, TCSC is more effective for transient stability improvement than the shunt FACTS devices such as SVC and STATCOM of multi machine system.

VI. CONCLUSION

The power system stability enhancement of a two area power system by various FACTS devices is presented and discussed. The performance of the TCSC for transient stability improvement is compared with the other shunt FACTS devices such as SVC, and STATCOM respectively. It is clear from the simulation results that there is a considerable improvement in the system performance with the presence of TCSC for which the settling time is found to be around 4.5 seconds.

REFERENCES

[1] [1] P. Kundur, “Power System Stability and Control”, EPRI Power System EngineeringSeries (Mc Graw-Hill, New York, 1994).

[2] K.R.Padiyar “FACTS Controllers in power transmission and distribution”,New Age International Publishers, 2007.

[3] N. G. Hingorani, “Flexible AC Transmission Systems,” IEEE Spectrum, pp. 40–45, Apr. 1993.

[4] N. Mithulananthan, C.A. Canizares, J. Reeve, Graham J. Rogers, 2003, “Comparison of PSS, SVC and STATCOM Controllers for Damping Power System Oscillations,” IEEE Transactions on Power Systems, 18(2), pp. 786-792.

[5] E.Z. Zhou, 1993, “Application of Static Var Compensators to Increase Power System damping,” IEEE Transactions on Power Systems, 8(2), pp. 655-661.

[6] N. G. Hingorani and L. Gyugyi, Understanding FACTS. Delhi, India:Standard , PublishersDistributors, 2001.

[7] L. Rajalakshmi, M. V. Suganyadevi, S. Parameswari, “Congestion Management in Deregulated Power System by locating Series FACTS devices.”IJCA , Volume 13-No 8, January 2011.

[8] Mehrdad Ahmadi Kamarposhti, Mostafa Alinezhad, Hamid Lesani, Nemat Talebi “Comparison of SVC ,STATCOM, TCSC and UPFC controllers for Static Voltage Stability Evaluated by Continuation Power Flow Method. IEEE Publications 2008.

[9] N.G. Hingorani, L. Gyugyi, 1999, “Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems,” IEEE Press, New York.

[10] C. Huang, C.J. Huang, and M. Wang, "A Particle swarm optimization to identifying the ARMAX model for short-term load forecasting," IEEE Trans. on Power Systems, vol. 20, no. 2, pp. 1126 1133, May 2005.