International Journal on Emerging Technologies **4**(2): 101-109(2013)
ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Comparison between SVC and STATCOM FACTS Devices for Power System Stability Enhancement

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(Received 15 July, 2013 Accepted 07 October, 2013)

ABSTRACT: The development of the modern power system has led to an increasing complexity in the study of power systems, and also presents new challenges to power system stability, and in particular, to the aspects of transient stability and small-signal stability. Transient stability control plays a significant role in ensuring the stable operation of power systems in the event of large disturbances and faults, and is thus a significant area of research. This paper investigates comparison of SVC and STACOM performance for the transient stability improvement of the two area multi machine power system. The improvement of transient stability of a two-area multi-machine power system, using SVC (Static VAR Compensator) STATCOM (Static Synchronous Compensator) which is an effective FACTS (Flexible AC Transmission System) device capable of controlling the active and reactive power flows in a transmission line by controlling appropriately parameters. Simulations are carried out in Matlab/Simulink environment for the two-area multi-machine power system model with SVC & STATCOM to analyze the effects of SVC & STATCOM on transient stability performance of the system. The performance of SVC & STATCOM is compared from each other. In comparative result STACOM gives the better result than SVC .So for the improvement of transient stability STATCOM is better than SVC. The simulation results demonstrate the effectiveness and robustness of the proposed STATCOM & SVC on transient stability improvement of the system.

Key words*:* FACTS, SVC, STATCOM Matlab/Simulink, Transient stability, Two-area Two machine power system and PSS.

I. INTRODUCTION

Modern power system is a complex network comprising of numerous generators, transmission lines, variety of loads and transformers. As a consequence of increasing power demand, some transmission lines are more loaded than was planned when they were built. With the increased loading of long transmission lines, the problem of transient stability after a major fault can become a transmission limiting factor [1]. Now power engineers are much more concerned about transient stability problem due to blackout in northeast United States, Scandinavia, England and Italy. Transient stability refers to the capability of a system to maintain synchronous operation in the event of large disturbances such as multi-phase short-circuit faults or switching of lines [2]. The resulting system response involves large excursions of generator rotor angles and is influenced by the nonlinear power angle relationship. Stability depends upon both the initial operating conditions of the system and the severity of the disturbance. Recent development of power electronics introduces the use of flexible ac transmission system (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 exploited to improve the voltage stability, and steady state and transient stabilities of a complex power system [3-4]. This allows increased utilization of existing network closer to its thermal loading capacity, and thus avoiding the need to construct new transmission lines. Static VAR Compensator (SVC) is a first generation FACTS device that can control voltage at the required bus thereby improving the voltage profile of the system. The primary task of an SVC is to maintain the voltage at a particular bus by means of reactive power compensation (obtained by varying the firing angle of the thyristors) [5]. SVCs have been used for high performance steady state and transient voltage control compared with classical shunt compensation. SVCs are also used to dampen power swings, improve transient stability, and reduce system losses by optimized reactive power control [6-7].

STATCOM, a shunt compensation device, from the family of flexible alternating current transmission systems (FACTS). The STATCOM is a solid-state voltage source converter which is tied to a transmission line. A STATCOM injects an almost sinusoidal current, of variable magnitude, at the point of connection. This injected current is almost in quadrature with the line voltage, thereby emulating an inductive or a capacitive reactance at the point of connection with the transmission line.

The benefits of utilizing FACTS devices in electrical transmission systems can be summarized as follows [1]. : Better utilization of existing transmission system assets

(i) Increased transmission system reliability and availability
(ii) Increased dynamic and transient grid stability and reduction of loop flows
(iii) Increased quality of supply for sensitive industries Environmental benefits Better utilization of existing transmission system assets.

II. 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 shunting 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. 1.

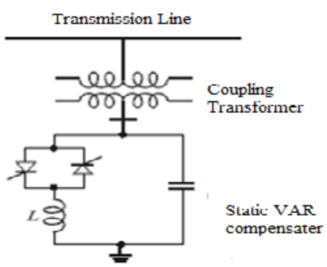

Fig. 1: Static VAR Compensator of SVC.

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.

III. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

The STATCOM is based on a solid state synchronous voltage source which generates a balanced set of three sinusoidal voltages at the fundamental frequency with rapidly controllable amplitude and phase angle. The con- figuration of a STATCOM is shown in Fig. 2.

Basically it consists of a voltage source converter (VSC), a coupling transformer and a dc capacitor. Control of the reactive current and hence the susceptance presented to power system is possible by variation of the magnitude of output voltage (VVSC) with respect to bus voltage (VB) and thus operating the STATCOM in inductive region or capacitive region.

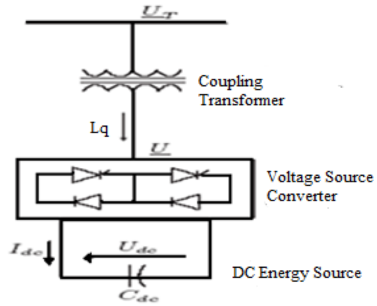

Fig. 2: Static Synchronous Compensator (STATCOM).

IV. POWER SYSTEM STABILIZERS

A PSS can be viewed as an additional block of a generator excitation controller AVR, added to improve the overall power system dynamic performance, especially for the control of electro mechanical oscillations. Thus, the PSS uses auxiliary stabilizing signals such as shafts peed, terminal frequency and/or power to change the input signal to the AVR this is a very effective method of enhancing small-signal stability performance on a power system network. The block diagram of the PSS used in the paper is depicted in Fig. 3. In large power systems, participation factors corresponding to the speed deviation of generating units can be used for initial screening of generators on which toad PSS.

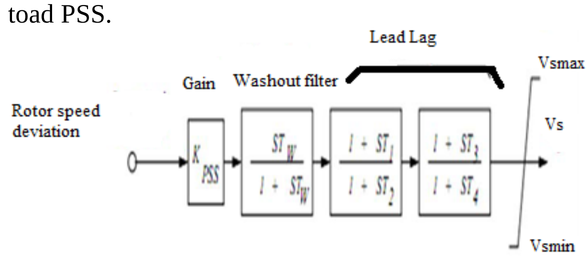

Fig. 3: PSS model used for simulations.

However, a high participation factor is a necessary but not sufficient condition For a PSS at the given generator to effectively damp oscillation. Following the initial screening a more rigorous valuation using residues and frequency response should be carried out to determine the most suitable locations for the stabilizers. [5-10].

V. MULTIMACHINE POWER SYSTEM MODEL

A 1000 MW hydraulic generation plant (M_1) is connected to a load centre through a long 500 kV, 700km transmission line. A 5000 MW of resistive load is modeled as the load centre. The remote 5000 MVA plant and a local generation of 5000 MVA (plant M_2) feed the load. A load flow has been performed on this system. The two machines are equipped with a hydraulic turbine and governor (HTG), ex-citation system, and power.

These components are included in 'Reg M_1' and 'Reg M_2' subsystem blocks, respectively. Initial power outputs of the generators are P_{ref1} = 0.95 pu and P_{ref2} = 0.809094 pu. Any disturbances that occur in power systems due to single line faults or 3-phase faults can result in inducing electromechanical oscillations of the electrical generators. Simulation model without any FACTS devices & PSS shown in Fig. 4.

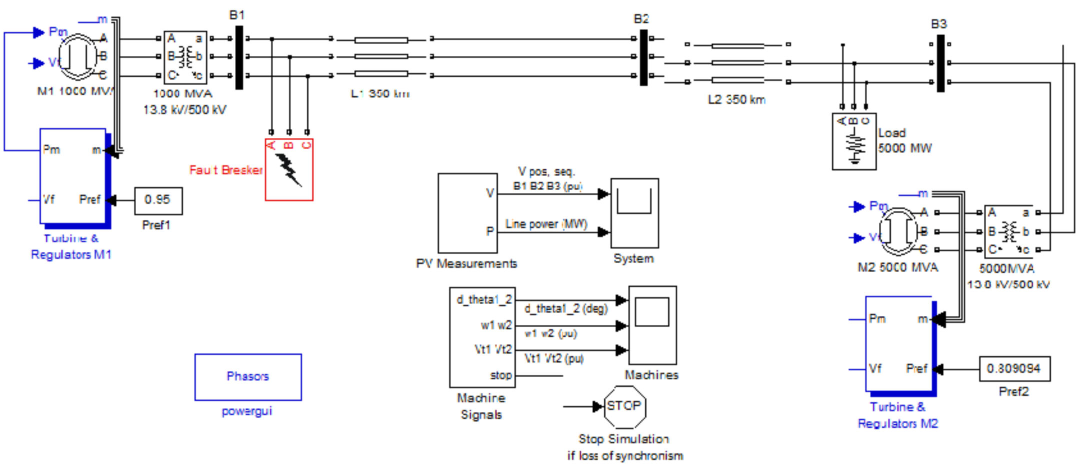

Fig. 4: Simulation of Test System without FACT Device & PSS.

VI. IMPACT OF SVC WITHOUT & WITH PSS

The simulation diagram of impact of SVC of two area multi machine system without & with PSS is shown in Fig. 5 & 6. To maintain system stability after faults, the transmission line is shunt compensated at its centre by a 200 MVA capacitive & 200MVA inductive Static VAR Compensator (SVC) shown in Fig. 5.

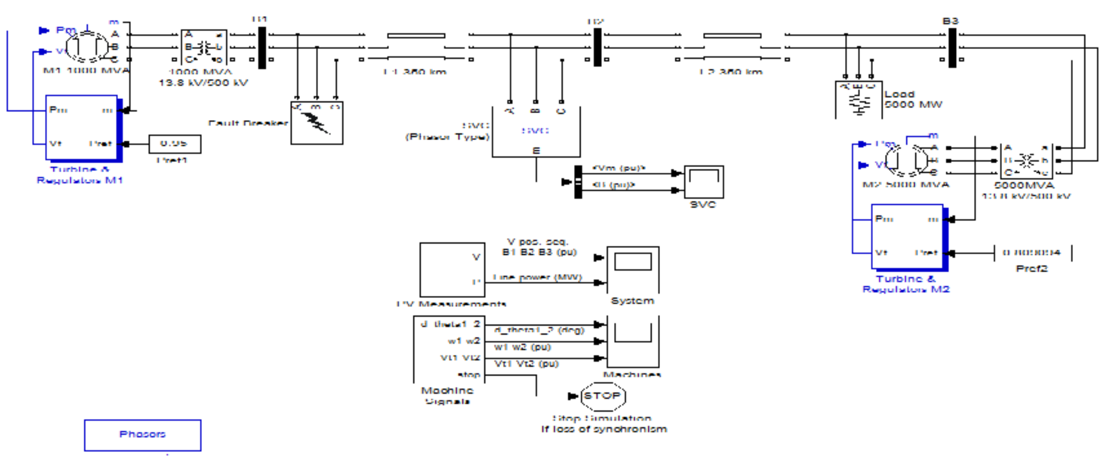

Fig. 5: Simulation of SVC Test System without PSS.

Oscillating swings must be effectively damped to maintain the system stability and reduce the risk of outage. To ensure robust damping SVC has been controller externally by properly deigned PSS. Model of SVC with PSS Shown in Fig. 6.

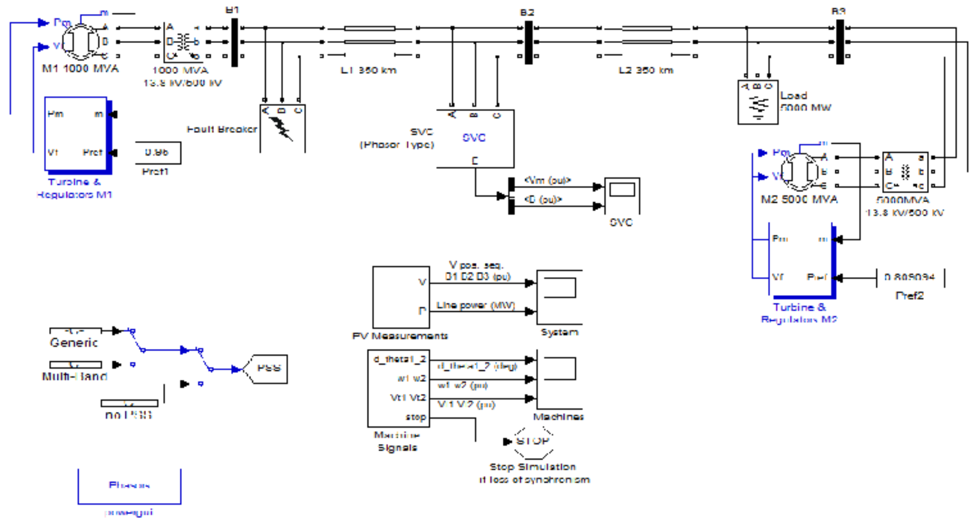

Fig. 6: Simulation of SVC Test System with PSS.

VII. IMPACT OF STATCOM WITHOUT & WITH PSS

The Static Synchronous Compensator (STATCOM) is one of the key FACTS devices. STATCOM output current (inductive or capacitive) can be controlled independent of the AC system voltage. The simulation diagram of two area multi machine system without & with PSS is shown in Fig.7 & 8 The Static Synchronous Compensator (STATCOM) is one of the key FACTS devices. STATCOM output current (inductive or capacitive) can be controlled independent of the AC system voltage. Model of STATCOM without PSS Shown in Fig. 7.

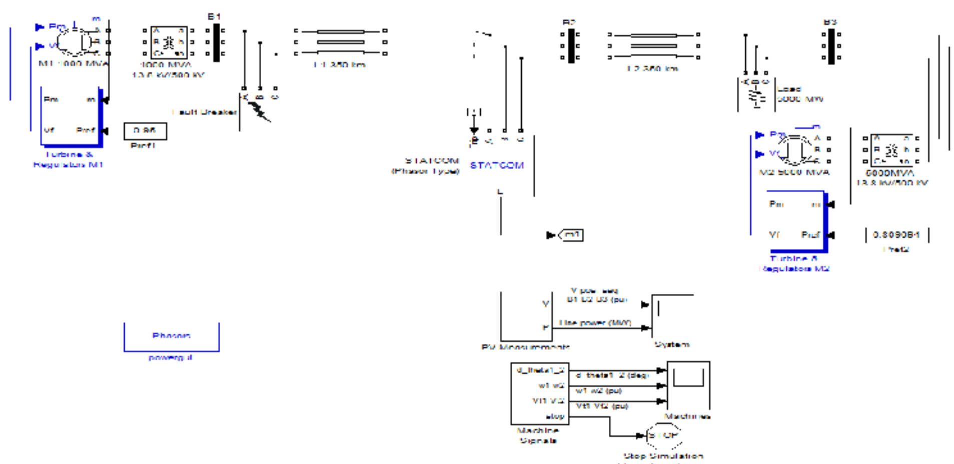

Fig. 7: Simulation of STATCOM Test System without PSS.

To control the oscillating swing in the multi machine system PSS must be connected in the system. Model of STATCOM with PSS Shown in Fig. 8.

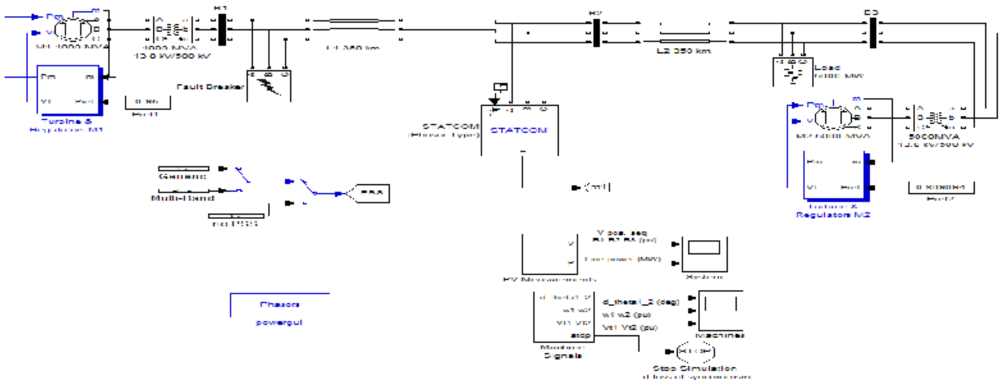

Fig. 8: Simulation of STATCOM Test System with PSS.

VIII. SIMULATION RESULTS WITHOUT FACTS AND PSS

A result shows the two area multi machine system without PSS. In this results without FACTS Device and PSS transient produced in system and settling time is very high. results of the bus voltage (B_1,B_2, B_3), line power, rotor angle deviation(δ), terminal voltages (v_{t1},v_{t2}) shown in Fig. 9 & 10.

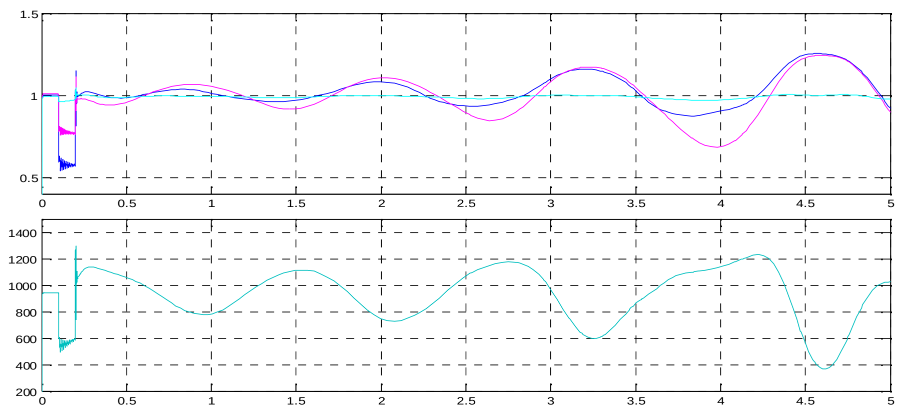

Fig. 9: Bus Voltages B_1, B_2, B_3 and Power.

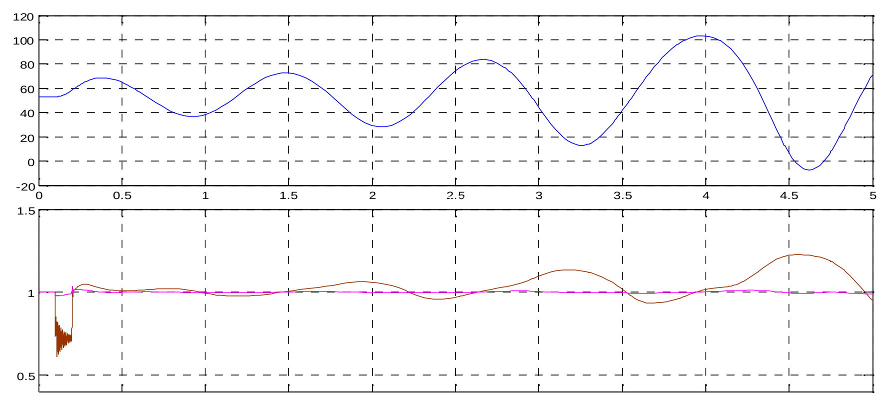

Fig. 10: Rotor Angle, Terminal Voltages V_{t1}, V_{t2}.

IX. SIMULATION RESULTS WITH SVC WITHOUT PSS

In this system result transient cannot reduce without PSS. So to reduce transients PSS must be connected in the system. results of the bus voltage(B_1, B_2, B_3), line power, rotor angle deviation (δ), terminal voltages (v_{t1},v_{t2}) is shown in Fig. 11 & 12.

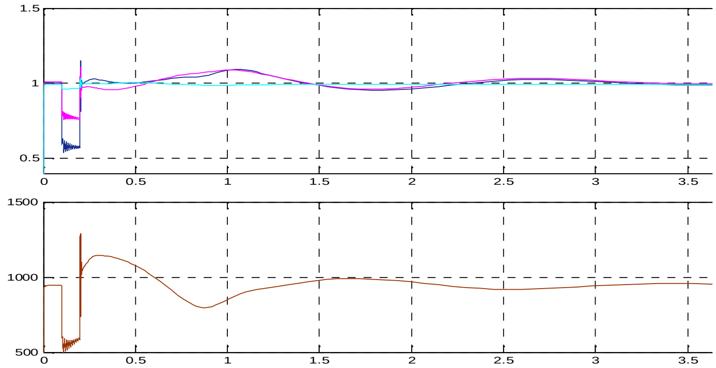

Fig. 11: Bus Voltages B_1, B_2, B_3 and Power.

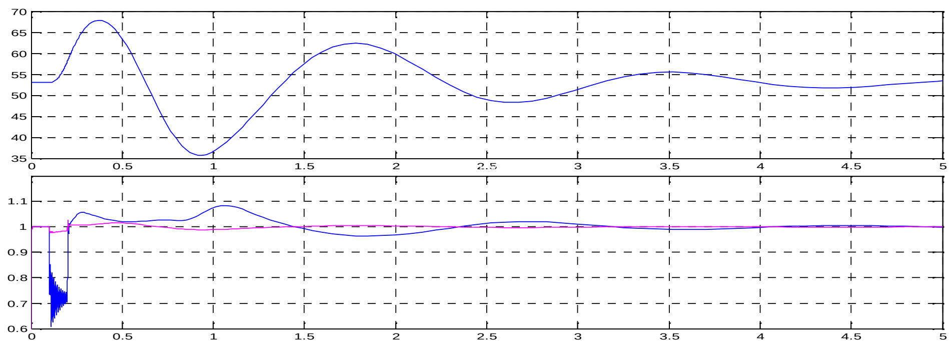

Fig. 12: Rotor Angle, Terminal Voltages V_{t1}, $V_{t2.}$

X. SIMULATION RESULTS WITH SVC AND PSS

When the PSS is connected in the system the system will become stable and transient will be reduce .so transient can be reduce by the use of PSS. With the help of PSS the terminal voltage is more stable during the fault occurring in the system. Results of the bus voltage (B_1, B_2, B_3), line power, rotor angle deviation (δ), terminal voltages (v_{t1},v_{t2}) is shown in Fig. 13 & 14.

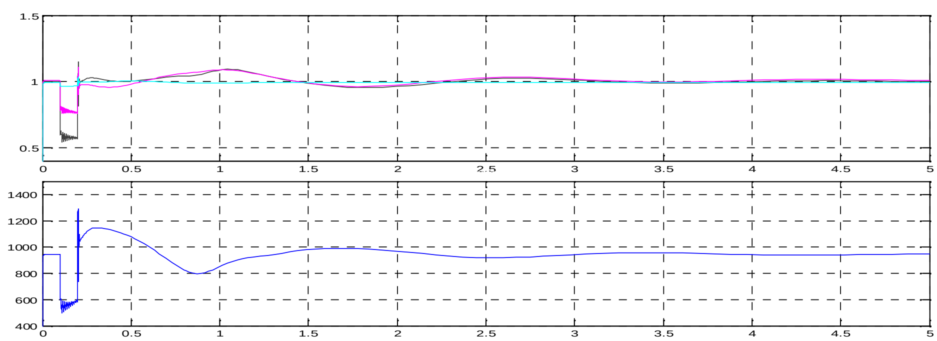

Fig. 13: Bus Voltages B_1, B_2, B_3 and Power.

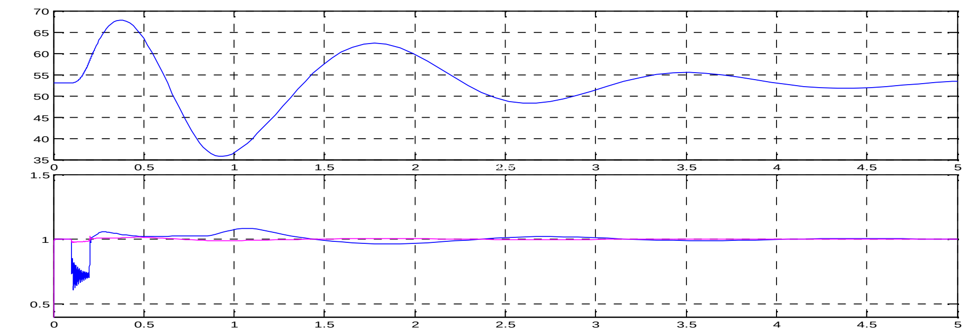

Fig. 14: Rotor Angle, Terminal Voltages V_{t1}, $V_{t2.}$

XI. SIMULATION RESULTS WITHSTATCOM & WITHOUT PSS

In this system transient reduce with the help of STATCOM. Bus voltage (B_1,B_2, B_3), line power(P), rotor angle deviation (δ), terminal voltages (v_{t1},v_{t2}) is shown in Fig. 15 & 16.

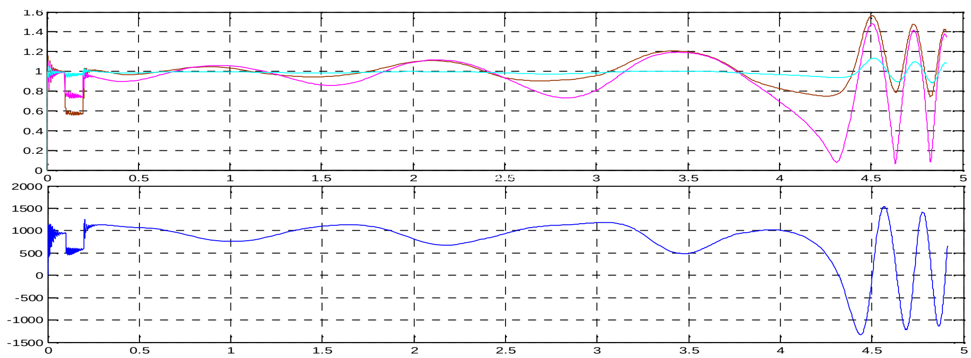

Fig. 15: Bus Voltages B_1, B_2, B_3 and Power.

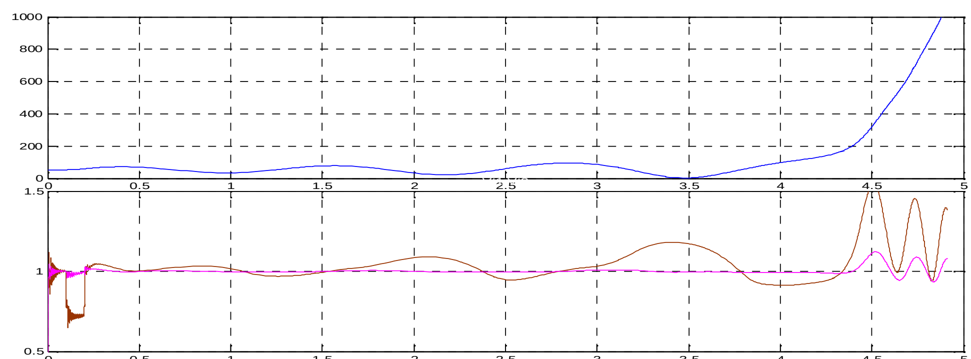

Fig. 16: Rotor Angle, Terminal Voltages V_{t1}, $V_{t2.}$

XII. SIMULATION RESULTS WITHSTATCOM & PSS

When fault occurs at 0.1 to 0.2 seconds the STATCOM gives more stable results than SVC. When PSS connected in the system the bus voltages and line power of system gives more stable results compare than without PSS. So the stability of system can improve by the use of PSS. When the PSS is connected in the system the system will become stable and transient will be reduce .mainly the oscillations in generator rotor angle deviation of area1 and area2 and line power stability can be improve by the use of PSS. Results of the bus voltage (B_1, B_2, B_3), line power, rotor angle deviation (δ), terminal voltages (v_{t1},v_{t2}) is shown in Fig.17 & 18. Voltage stability during fault occurred in the system is much better than without PSS.

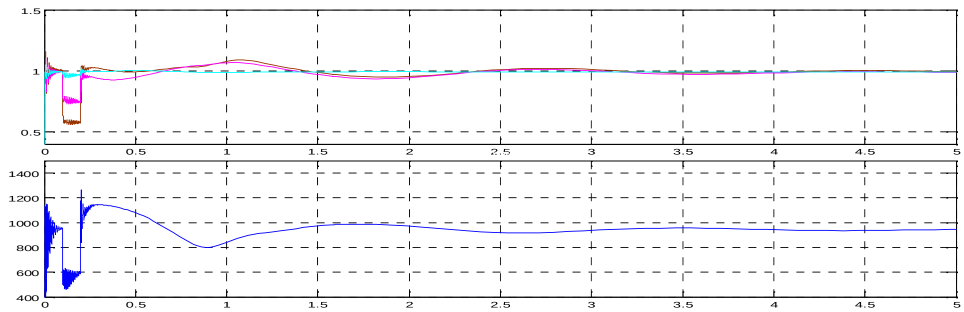

Fig. 17: Bus Voltages B_1, B_2, B_3 and Power.

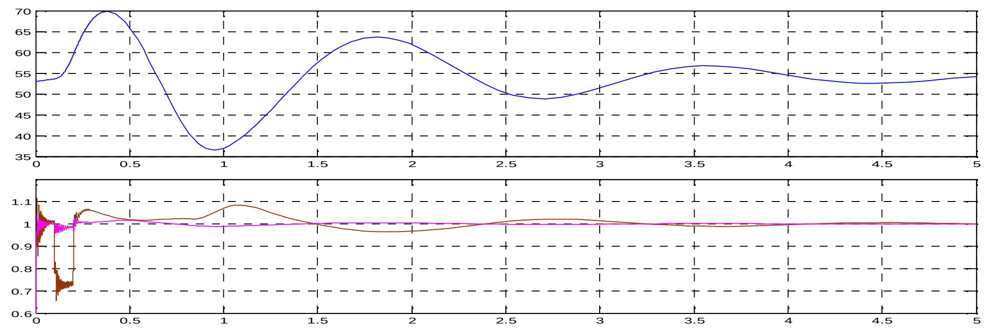

Fig. 18: Rotor Angle, Terminal Voltages V_{t1}, V_{t2}.

XIII. CONCLUSION

This Paper deals with applications of the SVC and STATCOM. The detailed models of the SVC and STATCOM were implemented and tested in MATLAB/Simulink environment. The models are applicable for voltage stability analysis. The effects of FACTS (SVC and STATCOM) installed in power transmission path are analyzed in this paper, and the conclusions are as follow:

- The STATCOM give superior performance than SVC for power measurement, bus voltages and rotor angle and terminal voltages of the multi-machine system.
- The best performance has been obtained by introducing FACTS devices such as SVC and STATCOM which compensate reactive power, it's concluded that by introducing FACTS device system performance, voltage stability and transmission capability improves considerably.

REFERENCES

[1]. R. Mihalic, P. Zunko and D. Povh, 1996, "Improvement of Transient Stability using Unified Power Flow Controller," IEEE Transactions on Power Delivery, **11**(1),pp. 485-491.

[2]. K.R. Padiyar, 2002, "Power System Dynamic Stability and Control," Second Edition, BS Publications, Hyderabad.

[3]. Igor Papic, Peter Zunko, 2002, "Mathematical Model and Steady State Operational Characteristics of a Unified Power Flow Controller,"Electro-technical Review, Slovenija, **69**(5), pp. 285-290.

[4]. S. Panda, Ramnarayan N. Patel, 2006, "Improving PowerSystem Transient Stability with an off-centre Location of Shunt FACTS Devices," Journal of Electrical Engineering, **57**(6), pp. 365-368.

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

[6]. 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.

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

[8]. H. SAADAT, H.: Power System Analysis, Tata McGraw-Hill, 2002.
[9]. N.G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. New York: IEEE Press, 2000.
[10]. N.G. Hingorani, “FACTS-Flexible AC Transmission System”, Proceedings of 5th International Conference on AC and DC Power Transmission-IEE Conference Publication 345, 1991, pp. 1–7.
[11]. N.G. Hingorani, “Flexible AC Transmission”, IEEE Spectrum, April 1993, pp. 40–45.
[12]. N.G. Hingorani, “High Power Electronics and Flexible AC Transmission System”, IEEE Power Engineering Review, July 1988
[13]. Habibur, Dr. Fayzur, Harun, ’Online voltage level im-provement by using SVC & PSS’ “International Jour-nal of system & simulation”. Vol. **06**, No.02(Dec,2012) Issue(Received for publication)
[14]. " MATLAB Math Library User's Guide", by the Math Works. Inc.
[15]. Amit Garg,”Modeling and Simulation of Static VAR Compensator for Improvement of Voltage Stability in Power System”ISSN: 2249-071X, Vol.**2**, Issue-2.
[16]. Ali M. Yousef “Transient stability Enhancement of multi machine using Global deviation PSS ” *Journal of Engineering sciences*, Faculty of Engineering, As-siut University, Vol. **32**, No.2 April 2004 pp. 665-677.
[17]. B.H. Li, Q.H. Wu, D.R. Turner, P.Y. Wang, X.X. Zhou, 2000, “Modeling of TCSC Dynamics for Control and
Analysis of Power System Stability,” *Electrical Power &Energy Systems*, **22**(1), pp. 43-49.
[18]. A.D. Del Rosso, C.A. Canizares, V.M. Dona, 2003, “A Study of TCSC Controller Design for Power System Stability Improvement,” *IEEE Transactions on Power Systems*, **18**(4), pp. 1487-1496.
[19]. L. Gyugyi, 1994, “Dynamic Compensation of AC Transmission Line by Solid State Synchronous Voltage Sources,” *IEEE Transactions on Power Delivery*, **9**(22), pp. 904-911.
[20]. M. Noroozian, L. Angquist, M. Ghandhari, G. Andersson, 1997, “Use of UPFC for Optimal Power Flow Control,” *IEEE Transactions on Power Delivery*, **12**(4), pp. 1629- 1634.
[21]. M. Ghandhari, G. Andersson, I.A. Hiskens, 2001, “Control Lyapunov Functions for Series Devices,” *IEEE Transactions on Power Delivery*, **16**(4), pp. 689-694.