*International Journal For Technological Research In Engineering*
*Volume 4, Issue 9, May-2017* *ISSN (Online): 2347 - 4718*

# IMPROVING POWER SYSTEM TRANSIENT STABILITY BY USING FACTS DEVICES

Muralidhar Verma[1], Shriyansh Jain[2]

***Abstract: 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. This paper investigates the improvement of transient stability of a two-area power system, using a SVC, STATCOM, UPFC, and TCSC. The performance of UPFC is compared with other FACTS devices such as Thyristor Controlled Series Capacitor (TCSC), (STATCOM) and Static Var Compensator (SVC) respectively. The simulation results demonstrate the effectiveness and robustness of the proposed UPFC on transient stability improvement of the system.***
***Keywords: FACTS, Matlab/Simulink, SVC, STATCOM, UPSC, TCSC, Transient stability, Two-area power system, UPFC***

## I. INTRODUCTION

The 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]. 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]-[8].

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 [9]. 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 [10]-[11].

Thyristor Controlled Series Capacitor (TCSC) is one of the important members of FACTS family that is increasingly applied with long transmission lines by the utilities in modern power systems. It can have various roles in the operation and control of power systems, such as scheduling power flow; decreasing unsymmetrical components; reducing net loss; providing voltage support; limiting short-circuit currents; mitigating sub synchronous resonance (SSR); damping the power oscillation; and enhancing transient stability [12]-[14].

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile one that can be used to improve steady state stability, dynamic stability and transient stability [16]. The UPFC can independently control many parameters since it is the combination of Static Synchronous Compensator (STATCOM). These devices offer an alternative mean to mitigate power system oscillations. It has been reported in many papers that UPFC can improve stability of single machine infinite bus (SMIB) system and multimachine system [17]-[18]. The inter-area power system has special characteristic of stability behaviour [19]. This paper investigates the improvement of transient stability of a two-area power system with a UPFC. A Matlab/Simulink model is developed for a two-area power system with a UPFC. The performance of UPFC is compared with other FACTS devices such as SVC, TCSC, and STATCOM respectively. From the simulation results, it is inferred that UPFC is an effective FACTS device for transient stability improvement.

## II. FACTS CONTROLLERS

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.

### *A. Static Var Compensator (Svc)*

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.Which basically consists of a fixed capacitor (C) and a thyristor controlled reactor (L). The firing angle control of the thyristor banks determines the equivalent shunt admittance presented to the power system.

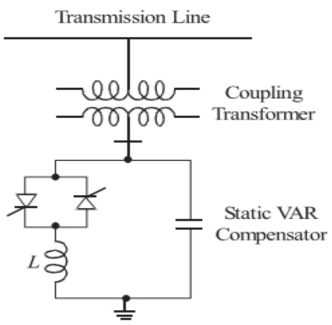



Fig.1 SVC connected to a transmission line.

*B. 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 configuration 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 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.

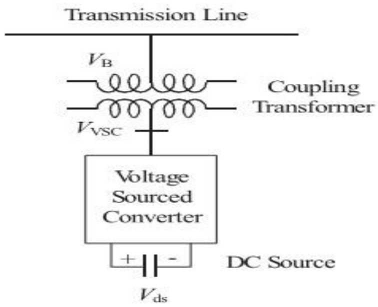



Fig.2 STATCOM connected to a transmission line.

*C. Thyristor Controlled Series Capacitor (TCSC)*

TCSC is one of the most important and best known FACTS devices, which has been in use for many years to increase the power transfer as well as to enhance system stability. The main circuit of a TCSC is shown in Fig. 3. The TCSC consists of three main components: capacitor bank C, bypass inductor L and bidirectional thyristors SCR1 and SCR2. The firing angles of the thyristors are controlled to adjust the TCSC reactance in accordance with a system control algorithm, normally in response to some system parameter variations. According to the variation of the thyristor firing angle or conduction angle, this process can be modeled as a fast switch between corresponding reactance's offered to the power system.

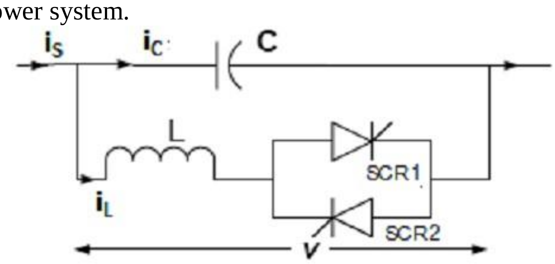



Fig.3 TCSC connected to a transmission line

*D. Unified Power Flow Controller (UPFC)*

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile one that can be used to enhance steady state stability, dynamic stability and transient stability. The basic configuration of a UPFC is shown in Fig. 4. The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac/dc converters. One of the two converters is connected in series with the transmission line through a series transformer and the other in parallel with the line through a shunt transformer. The dc side of the two converters is connected through a common capacitor, which provides dc voltage for the converter operation. The power balance between the series and shunt converters is a prerequisite to maintain a constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit. The shunt converter exchanges a current of controllable magnitude and power factor angle with the power system. It is normally controlled to balance the real power absorbed from or injected into the power system by the series converter plus the losses by regulating the dc bus voltage at a desired value.

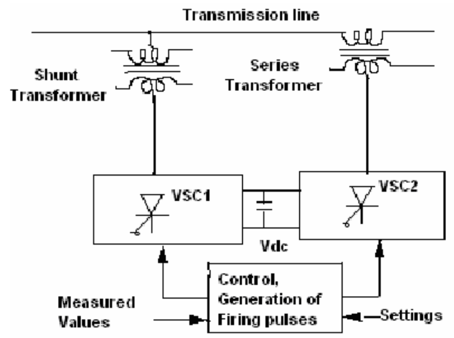



Fig.4 UPFC connected to a transmission line

III. TWO AREA POWER SYSTEM MODEL

Consider a two-area power system (Area-1 & Area- 2) with series and shunt FACTS devices, connected by a single circuit long transmission line as shown in Fig. 5 and Fig. 6. Here, the FACTS devices such as UPFC (combination of STATCOM and SSSC), SSSC, and TCSC are equipped between bus-2 and bus-3 and the shunt FACTS device such as SVC is equipped at bus-2. The direction of real power flow is from Area-1 to Area-2. In the two-area power system model, the Area-1 consists of Generator 1 (G1) and Generator 2 (G2) and the Area-2 consists of Generator 3 (G3) and Generator 4 (G4). The system data are given in [21].

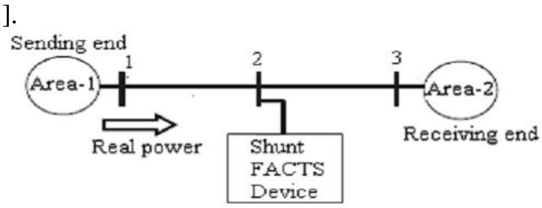



Fig.5 Two-area power system with FACTS device

## IV. SIMULATION MODEL

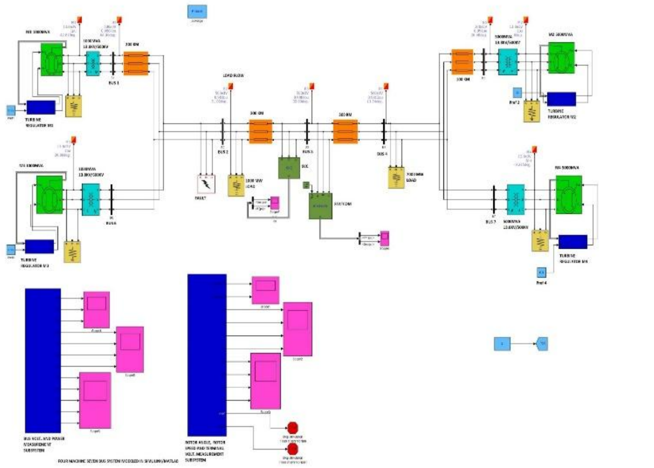
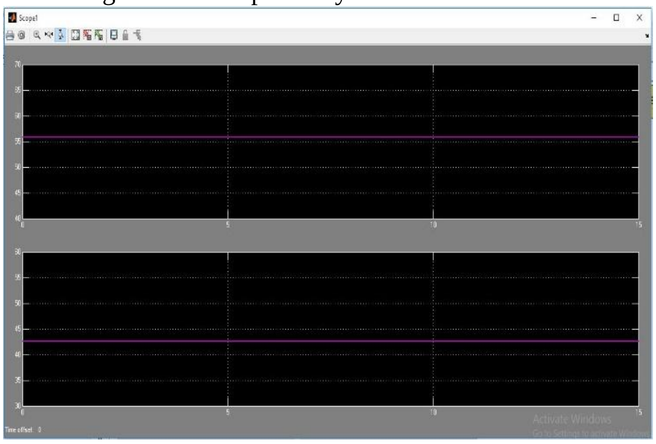
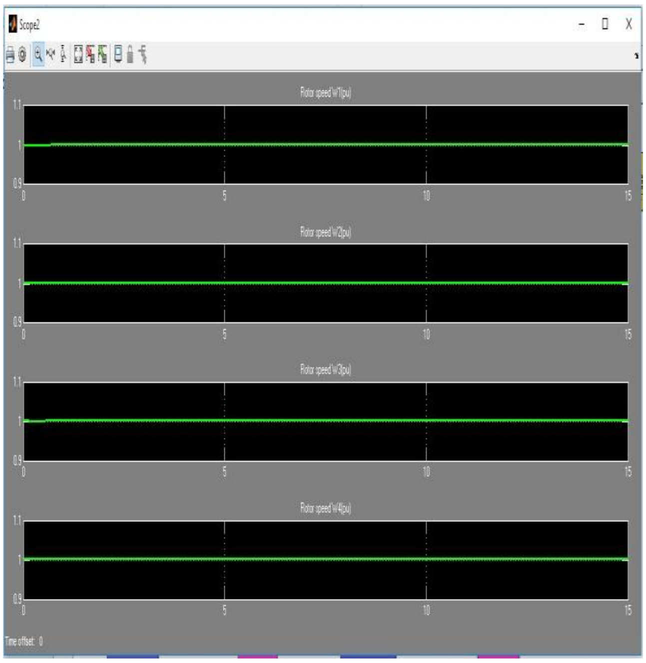


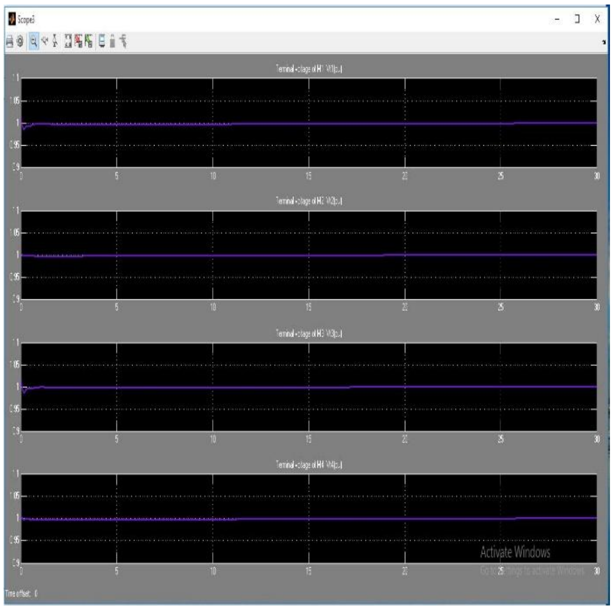
Fig.6 Two-area power system with STATCOM



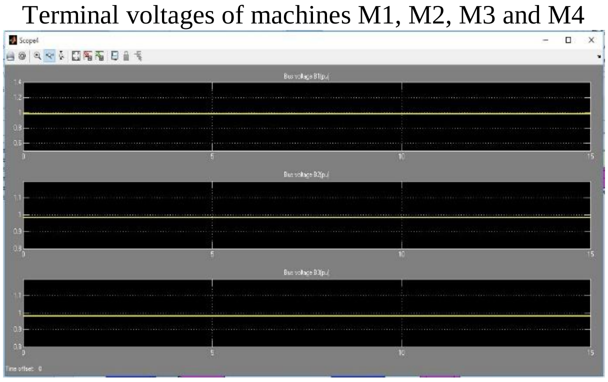
Rotor angle difference of G1&G2 and G3&G2

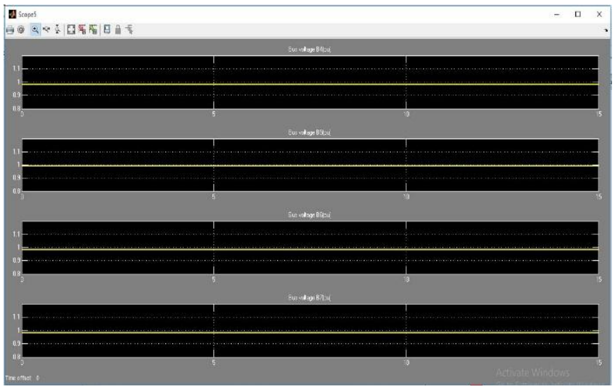


W1, W2, W3 and W4Rotor speed of machines M1, M2, M3 and M4



Terminal voltages of machines M1, M2, M3 and M4





Voltages at different Buses B1, B2, B3, B4, B5, B6 and B7 when system is under healthy condition the response of bus voltage of bus B1, B2, B3, B4, B5, B6 and B7 gives 1pu, 1pu, 1pu, 1pu, 1pu, 1pu and 1pu respectively. It has been observed that response of bus voltages have transient free response under healthy condition.

## V. COMPARISON BETWEEN UPFC, SVC, TCSC, AND SSSC FOR POWER SYSTEM STABILITY ENHANCEMENT

From the simulation results shown in Figs. A comparison is made between the above FACTS devices for stability enhancement of two-area power system under study as shown in Table 1

Table1: Comparison between FACTS Devices for Power System Stability Enhancement

| Two-area Power System with | Power System Stability Enhancement | Settling time in post fault period (in seconds) |
|---|---|---|
| STATCOM | YES | 0.4 |
| SVC | YES | 0.7 |
| TCSC | YES | 0.5 |
| UPFC | YES | 0.3 |

From the Table 1, it is investigated that the UPFC is the effective FACTS device for stability enhancement of inter-area power system.

## VI. CONCLUSION

The power system stability enhancement of a two area power system by various FACTS devices is presented and discussed. The dynamics of the system is compared with and without the presence of UPFC in the system in the event of a major disturbance. Then the performance of the UPFC for power system stability improvement is compared with the other FACTS devices such as SVC, TCSC, and STATCOM respectively. It is clear from the simulation results that there is a considerable improvement in the system performance with the presence of UPFC for which the settling time in post fault period is found to be around 0.3 second.

## 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] .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] Prechanon Kumkratug, 2009, "Application of UPFC to Increase Transient Stability of Inter-Area Power System," Journal of Computers, 4(4), pp. 283-287.

[5] Prechanon Kumkratug, Panthep Laohachai, 2007, "Direct Method of Transient Stability Assessment of a Power System with a SSSC," Journal of Computers, 2(8), pp. 7782.

[6] S.V. Ravi Kumar, S. Siva Nagaraju, 2007, "Transient Stability Improvement using UPFC and SVC," ARPN Journal of Engineering and Applied Sciences, 2(3), pp. 3845.

[7] A. Kazemi, F. Mahamnia, 2008, "Improving of Transient Stability of Power Systems by Supplementary Controllers of UPFC using Different Fault Conditions," WSEAS Transactions on Power Systems, 3(7), pp. 547-556.

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

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

[10] 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.

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

[12] P. Mattavelli, G.C. Verghese, A.M. Stankovic, 1997, "Phasor Dynamics of Thyristor-Controlled Series Capacitor Systems," IEEE Transactions on Power Systems, 12(3), pp. 1259-1267.

[13] 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.

[14] 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.

[15] L. Gyugyi, 1994, "Dynamic Compensation of AC Transmission Line by Solid State Synchronous VoltageSources," IEEE Transactions on Power Delivery, 9(22), pp. 904-911.

[16] 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. 16291634.

[17] M. Ghandhari, G. Andersson, I.A. Hiskens, 2001, "Control Lyapunov Functions for Series Devices," IEEE Transactions on Power Delivery, 16(4), pp. 689-694.

[18] P. Kumkratug, M.H. Haque, 2003, "Versatile Model of a Unified Power Flow Controller in Simple System," IEE Proc. Gener. Transm. & Distrib., 150(2), pp. 155-161.

[19] V. Vittal, N. Bhatia, A.A. Fouad, 1991, "Analysis of the Inter-area Mode Phenomenon in Power Systems Following Large Disturbances," IEEE Transactions on Power Systems, 6(4), pp. 1515-1521.

[20] R.M. Mathur, R.K. Varma, 2002, "Thyristor -based FACTS Controllers for Electrical Transmission Systems," IEEE Press, Piscataway.

[21] P. Kundur, 1994, "Power System Stability and Control," McGraw-Hill, New York.