IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-12, Dec 2018 E-ISSN: 2347-2693

Enhancement of Power System Stability using FACTS devices

Shailesh U. Kakaiya[1*], Okumu Cephas[2], Geeta N. Paichaure[3], Bhupendra R. Parekh[4]

[1,2,3,4]Department of Electrical Engineering, BVM Engineering College, Vallabh Vidyanagar, India

*Corresponding Author: kakaiyashailesh@gmail.com, Tel.: +91-8200331530

Available online at: www.ijcseonline.org

Accepted: 26/Dec/2018, Published: 31/Dec/2018

***Abstract*—** The dynamic system damping can be measured by using the rate of dissipation of transient energy. This paper deals with the different control methods for minimizing unwanted electromechanical perturbations and disturbances in power system with STATCOM (Static Compensator), SSSC (Static Synchronous Series Capacitor), and UPFC (Unified Power Flow Controller). A SMIB (Single Machine Infinite Bus) was simulated under several variations of situations. The results concluded depicts the functionality and robustness of these devices on power system stability.

***Keywords*—** FACTS, STATCOM, TCSC, UPFC, Stability, Generator output power, Rotor Angle

I. INTRODUCTION

From several time spans, one of the most areas of interest has remained in the enhancement, improvement and maintaining stability in power system. This area is becoming a challenge gradually due to the more consumption of electricity and due to the interconnection between various power systems. Also on the other hand energy utilization and its use are increasing due to rapid development which weakens transmission networks and this increases overall maintenance, manufacturing and transmission costs. Also, the electrical power system is subjected to many uncertainties, disturbances and perturbations like short circuits, over voltages, under voltages, etc. The disturbance in equilibrium between electrical power and mechanical power can affect the changes in speed of rotor leading to full or half outage. During previous years, it was advisable to use power system stabilizers to damp out the perturbations from the electrical power systems. Currently, different researchers visualize that FACTS devices provide an option to meet and overcome power system disturbances and instabilities. [1]

The effectiveness and influence of these devices like STATCOM, TCSC and UPFC are much dominant in the power system stability. The various conclusion deducted from studies is that each device is capable to improve the performance of system and damp out oscillations up to a certain level of extent.

The outline of this paper is as follows: Starting with mathematical modelling without FACTS devices and then simulating it in presence with FACTS devices, moving forward to results and deductions and concluding with some references. [2]

II. STUDIED MODEL OF POWER SYSTEM

Taking the following power system model under consideration having an AC generator interconnected to a bus which is of infinite source and is connected by a step-up transformer and a parallel circuit line. [3]

V_t and V_b indicates the value of machine voltage and voltage of infinite bus. The respective system circuit diagram is as shown in figure below Figure II.II

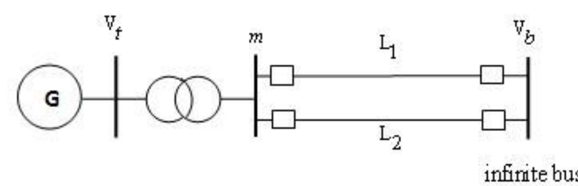


Figure II.I. Single machine infinite bus diagram

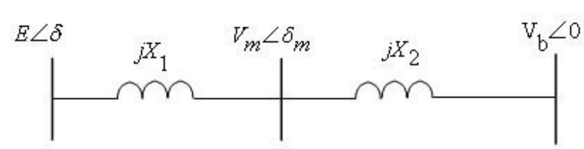


Figure II. II. Single machine infinite equivalent circuit diagram

X_1 shows the reactance of transformer, X_t adding machine reactance $X_{d'}$ and X_2 shows reactance X_{L1} and X_{L2} of parallel circuit line.

The electrical output power of the system is given by equation:

$$P_e = \frac{EV_b}{X_1 + X_2} sin\delta$$

III. POWER SYSTEM MODEL USING STATCOM

The device STATCOM is a VSC (Voltage Source Converter) having ability of supplying and taking excessive amount of reactive power from the system at its system terminal. It is shown by a reactive current source connected in parallel as displayed in figure III. I. Here, STATCOM is connected as bus m.

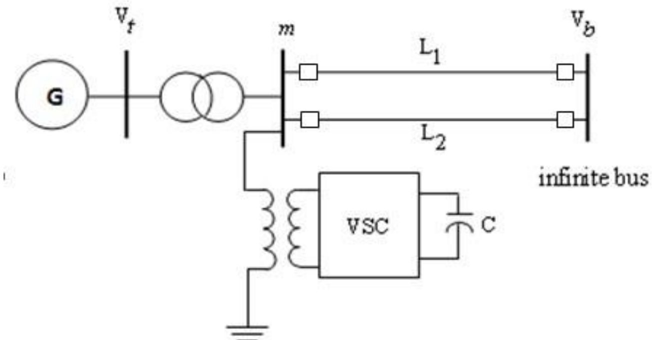


Figure III.I. Circuit diagram of SMIB with STATCOM

The equivalent circuit diagram of the system circuit is displayed below:

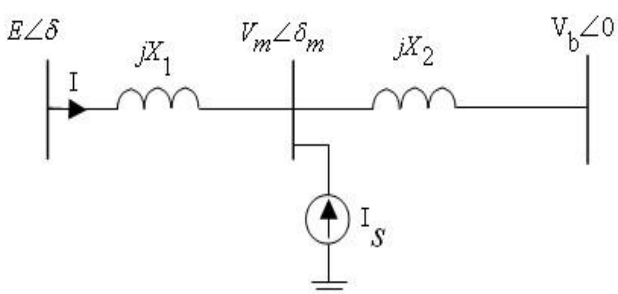


Figure III. II. Equivalent circuit diagram of SMIB with STATCOM.

The expression of the electrical power in the system in presence of STATCOM is given as under:

$$P_e = \frac{EV_b}{X_1 + X_2} sin\delta + \frac{EX_2}{X_1 + X_2} \sin(\delta - \delta_m) I_s$$

Here P_e is changed by injecting or absorbing current in the shunt which is having dynamic relationship with rotor speed perturbation. [3]

IV. POWER SYSTEM MODEL USING SSSC

A SSSC is mainly a Voltage-source device and acts as an inverter by generating a controllable alternating voltage source, and interconnected in series with transmission grid of the power system as shown in the figure IV.I

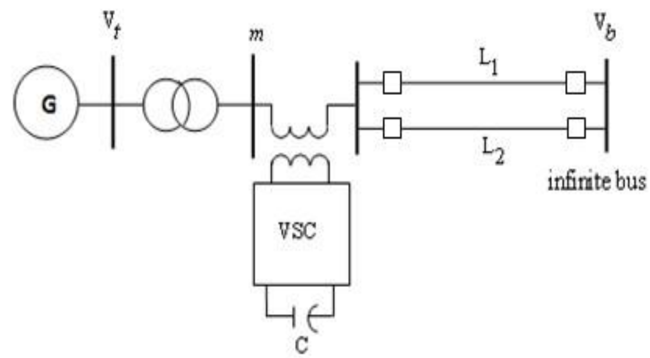


Figure IV.I. Circuit diagram of SMIB with SSSC

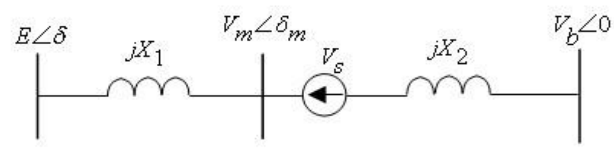


Figure IV. II. Equivalent circuit diagram of SMIB with SSSC

A SSSC is shown by a series voltage source which is connected to a transmission circuit via a leakage transformer reactance as displayed in figure IV.II

Here, the equation of the electrical power transfer is written as:

$$P_e = \frac{EV_b}{X_1 + X_2} sin\delta(1 + \alpha)$$

$$\alpha = \frac{V_s}{\sqrt{E^2 + V_b^2 - 2EV_b cos\delta}}$$

P_e is mostly controlled by series injected voltage. Therefore, it is non-negative when SSSC operations in non-inductive mode. [4]

V. POWER SYSTEM MODEL USING UPFC

A UPFC (Unified power flow controller) is the most versatile device in the FACTS family. The device has capability to manipulate three control factors. The line reactance, Phase angle between two adjacent buses and the magnitude of the voltage of bus with its flexibility of characteristics of a STATCOM and SSSC. In short, UPFC is a hybrid device consisting features of two FACTS devices namely STATCOM and SSSC. [5]

The real and reactive power in the system is being exchanged by the series converter in transmission line changing its phase angle and the magnitude of the injected voltage.
The function of the shunt converter is to convey real power demanded by the series converter by making common link as a passage. It also generates and absorbs reactive power.
The equivalent of UPFC is as shown below in the figure:

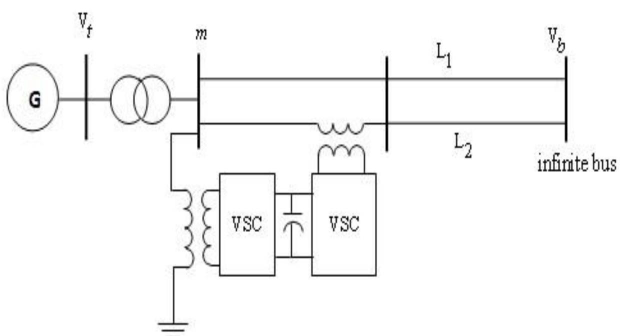


Figure V. I. Circuit diagram of SMIB with UPFC

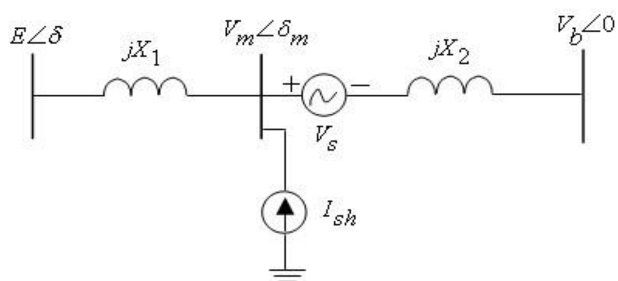


Figure V. II. Equivalent circuit diagram of SMIB with UPFC

The equivalent circuit of UPFC mainly comprises of the series voltage source and a shunt current source.
UPFC is an ammalgamtion of the various features and characteristics of both the FACTS devices that inclues SSSC and STATCOM. [6]
Thus, UPFC shows the superior enhancement in the transient stability performance of a single machine infinte bus system (SMIB System).

VI. Results and Deductions

A three phase symmetrical fault occurs into the transmission line in bus m. The fault is initiated at time t=1s and is removed by disconnecting line 2. Perturbations of rotor angle behaviour to the disturbances for various critical time is observed as shown in the below figure.

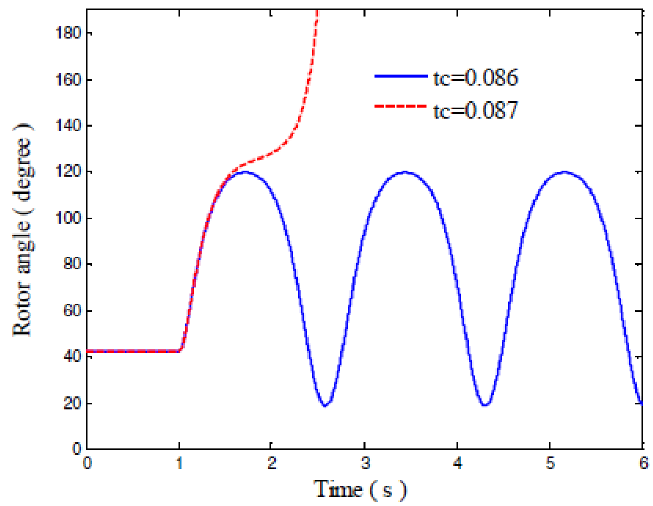


Figure VI.I. Relative angle position for different critical times

It shows that power system maintains its stability with the critical clearing time t_c=0.086 second. Also, rotor angle fluctuations are higher near a stable point. And it is instable with t_c=0.087 second. Therefore, rotor angle approaches to an infinite value. [7]
Therefore, the CCT (critical clearing time) is 0.0865+0.0005 seconds. At critical time t_c=0.0088 seconds the similar graph for SMIB in presence and absence of FACTS device are shown below:

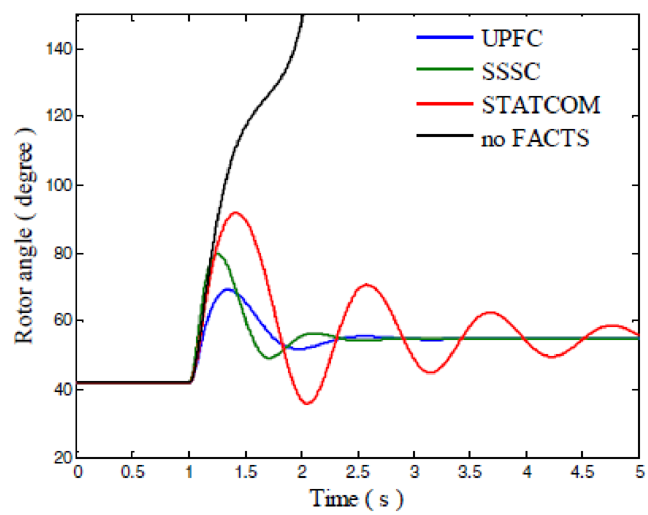


Figure VI. II. Relative angle position

SMIB scheme is edited under the various disturbances. Hence, the values of rotor angle after the fault and before the fault are not similar. These values are approximately 41.77° and 54.73°.
The figure VI.II depicts that the line without FACTS is not stable. When there is presence of FACTS device, the system is not unstable and oscillations are damped out and system gets stabilized to a certain acceptable extent. [8]

This is can more be enhanced by inserting UPFC. So that it can be concluded that UPFC as well as SSSC are more superior and exhibit a better performance than STATCOM.
Since these devices shows quick removal of perturbations from the system at time t=2s and but with STATCOM is at t=5s.
The figure below shows the graph of relative angle in the presence and absence of FACTS devices.

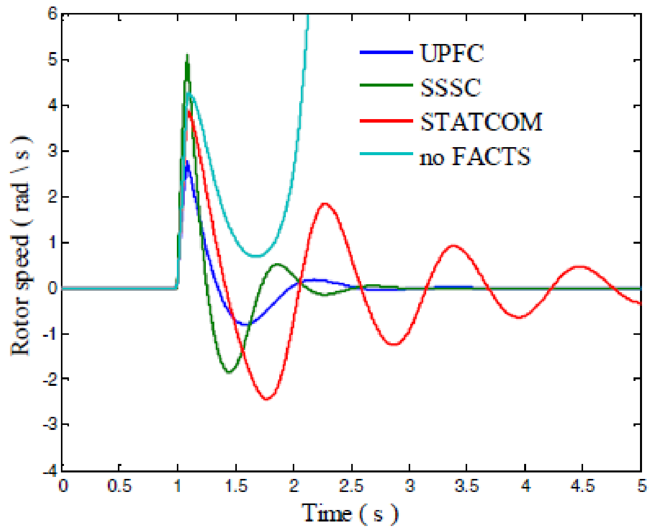


Figure VI.III. Relative angle velocity

The figure below shows the behaviour of Generator output power in presence and absence of FACTS devices. [9]

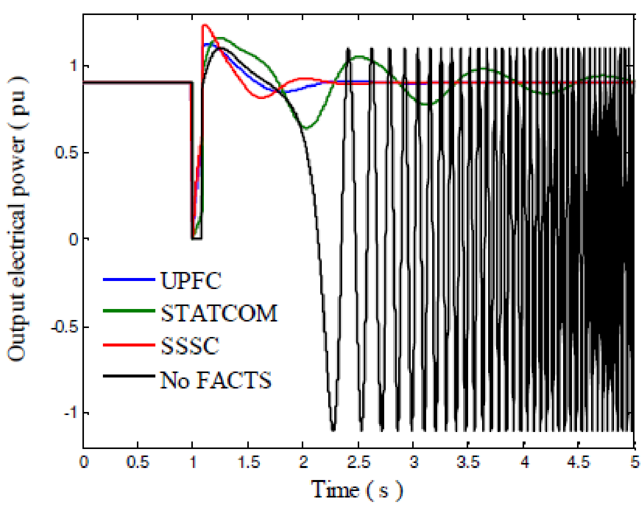


Figure VI. IV. Generator output power

The electrical output power in the case of before fault is approximately its value to 0.9 per unit.
At exactly 1 sec., the oscillations are not changed during period of fault and period after fault for the uncompensated case.
For the case which includes the FACTS devices, perturbations are quickly removed out from the system. For the case of presence of STATCOM, the electrical output power acquires its value of before fault which is 0.9 per unit in time span of 5 second. But here also, SSSC and UPFC shows a superior performance than STATCOM in the power system. [10]

VII. Conclusion

The principle of this study was to implement better control of a power system and FACTS devices under several disturbances and conditions. The mathematical model to include various devices like SSSC, STATCOM and UPFC into the power system and the controller structure proposed are analyzed here in the current research paper. The performance of the proposed method is simulated over some various cases and various parameters are observed under presence of all three FACTS devices. All the above aspects show the effectiveness of these devices to damp out oscillations and enhancing the electrical power system.

Acknowledgment

With the submission of this paper titled “Enhancement of Power System Stability using FACTS devices” I would express my gratitude and sincere thanks to Dr. B.R.Parekh, Electrical Engineering department, BVM Engineering College and IJCSE for providing me the every possible help and his tremendous motivation. I appreciate his encouragement and excellent guidance. I will remember his knowledge and help at the time of crisis, for my entire lifetime. Last but not the least I would also like to thank the entire staff members of my college for letting me know the knowledge I aspired for.

References

[1] E.V. Larsen, D.A. Swann. Jones, “Applying power system stabilizers Parts I and II”, *IEEE Trans.PAS, vol*. 100, pp. 3017–3046. 1981.

[2] M.Noroozian, L. Anguish, M. Bhandari, and Anderson, “Use of UPFC for optimal power flow control”, *IEEE Trans. on Power Systems, vol*. 12, no. 4, pp. 1629–1634. 1997.

[3] Mehrdad Ahmadi Kamarposhti, MostafaAlinezhad, “Effects of STATCOM, TCSC, SSSC and UPFC on Static Voltage Stability”, *International Review of Electrical Engineering, vol*. 4, no. 6, pp. 1376–1382. 2009.

[4] E. Z. Zhou, “Application of Static VAR Compensators to increase Power System Damping”, *IEEE Transactions on Power System, vol*. 8, no. 2, pp. 655–661. 1993.

[5] P. Kundur, *Power System Stability and Control*, Example13.1, page 863 McGraw-Hill, New York, 1994.

[6] Siddhartha Panda and Cardio, “Real coded genetic algorithm for robust power system stabilizer”, *World Academy of Science Engineering and Technology*, vol. 45, pp.571 –579.2008.

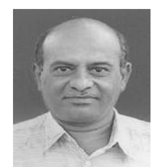
[7] M.H. Hague, "Improvement of first stability limit by utilizing full benefit of shunt FACTS devices", *IEEE transactions on power systems*, vol. 19, no.4, pp. 1894 – 1902. November 2004.
[8] H.F. Wang, "Static synchronous series compensator to damp power system oscillations", *Electric Power System Research*, vol.54, no.4, pp.113–119. 2000.
[9] "Optimal allocation and sizing of SSSC controller to minimise power production cost and transmission loss" by Shuma Adikari and Nidul Sinha, International Journal of Computer Science and Engineering, Vol.7, Issue 3, July 2012
[10] Eskandar Gholipour and Shahrokh Saadate, "Improving Transient Stability of Power Systems" International Journal of Computer Science and Engineering.

Authors Profile

Shailesh U. Kakaiya is pursuing his Master of Technology in specialization area of Power Systems from Birla Vishakarma Mahavidyalaya. It will get finished In May 2019. He has completed his Bachelor of Engineering from LDRP-ITR at Gandhinagar. His area of interest and work is more focussed on FACTS controller and transient Stability in his final year disseration.

Okumu Cephas is pursuing his Master of Technology in specialization area of Power Systems from Birla Vishakarma Mahavidyalaya. It will get finished In May 2019. He has completed his Bachelor of Engineering from Kampala International University. His area of interest and work is more focussed on Power system protection and FACTS devices in his final year disseration.

Geeta N. Paichaure is pursuing her Master of Technology in specialization area of Power Systems from Birla Vishakarma Mahavidyalaya. It will get finished In May 2019. She has completed her Bachelor of Engineering from Babaria Institute of Technology, Vadodara. Her area of interest and work is more focussed on Analysis of Micro-grid and in his final year disseration.



Dr. B. R. Parekh is Head of Department of Electrical Engineering Department of Birla Vishvakarma Mahavidyalaya. He has completed his research work in area of HVDC Transmission. He has several years of experience in academic area.