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Modeling, Analysis and Comparison of Various FACTS Devices in Power System

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ABSTRACT: Modeling and simulation of Static synchronous compensator (STATCOM), Static synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) for power system stability enhancement and improvement of power transfer capability have been presented in this paper. First, power flow results are obtained and then power (real and reactive power) profiles have been studied for an uncompensated system and then compared with the results obtained after compensating the system using the above-mentioned FACTS devices. The simulation results demonstrate the performance of the system for each of the FACTS devices in improving the power profile and thereby voltage stability of the same. All simulations have been carried out in MATLAB/SIMULINK environment.

Keywords: Voltage Stability, STATCOM, SSSC, UPFC, FACTS

I. INTRODUCTION

Modern power system is complex and it is essential to fulfill the demand with better power quality. Advanced technologies are nowadays being used for improving power system reliability, security and profitability and due to this power quality is improved. Voltage stability, voltage security and power profile improvement are essential for power quality improvement. To achieve optimum performance of power system it is required to control reactive power flow in the network. Construction of new transmission lines and power stations increase the problem of system operation as well as the overall cost. Regulatory limitation on the expansion of system network has resulted in reduction in stability margin thereby increasing the risk of voltage collapse [1]. Voltage collapse occurs in power system when system is faulted, heavily loaded and there is a sudden increase in the demand of reactive power. Voltage instability in power system occurs when the system is unable to meet the reactive power demand.

Reactive power imbalance occurs when there is a sudden increase or decrease in reactive power demand in the system. The only way to prevent the occurrence of voltage collapse is either to reduce the reactive power load or to provide the system with additional supply of reactive power before the system reaches the point of voltage collapse. This can be done by connecting sources of reactive power, *i.e.,* shunt capacitors and/or Flexible AC Transmission System (FACTS) controllers at appropriate locations in the system.

Flexible AC Transmission Systems (FACTS) technology helps utilities in reducing transmission congestion and in utilizing more efficiently the existing transmission system without compromising the reliability and security of the system. Their fast response offers high potential for power system stability enhancement apart from steady state flow control. The benefits of employing FACTS are aplenty: (a) They help to increase the power transfer capability of existing transmission systems, (b) They can directly control real and reactive power flow, (c) Provide fast dynamic reactive power support and voltage control, (d) Improve system stability and damp power system oscillations, (e) Reduce financial costs and environmental impact by possible deferral of new transmission lines.

FACTS devices have been defined by the IEEE as "alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability" [2-3]. There are five well known FACTS devices namely [4-5]: Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM) [6], Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC). Each of them have their own characteristics and limitations. It would be very effective if we could improve voltage stability by incorporating the most beneficial FACTS device for a given operating condition [7-8].

II. SYSTEM MODEL

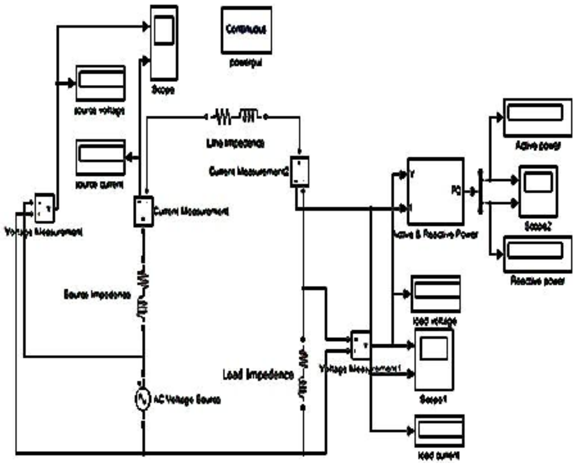

Fig. 1. Basic Transmission Line Model.

The above diagram shows a simplified model of an uncompensated system. The system is modeled in SIMULINK platform. The model is supplied from an 11 kV voltage source. The source impedance (0.01+j0.001)Ω, line impedance (10+j0.028)Ω and the load is kept constant at 30 MW and 60 MVAR for the above transmission line model. The scopes provided displays the signals generated during the simulation. In the above figure, two scopes are provided: one displays the source voltage and current, and the other displays the Load Voltage (VL), Load Current (IL), Real and Reactive Power at the receiving end. The results obtained after simulation are shown below:

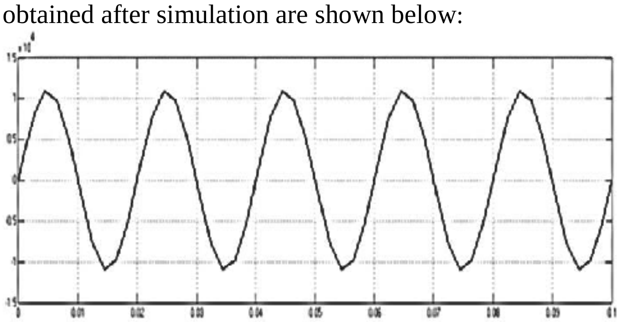

Fig. 2. Source Voltage.

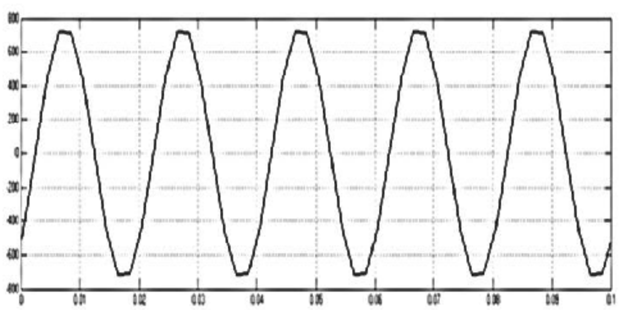

Fig. 3. Source Current.

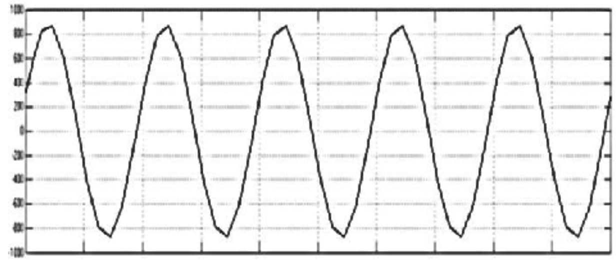

Fig. 4. Load Voltage.

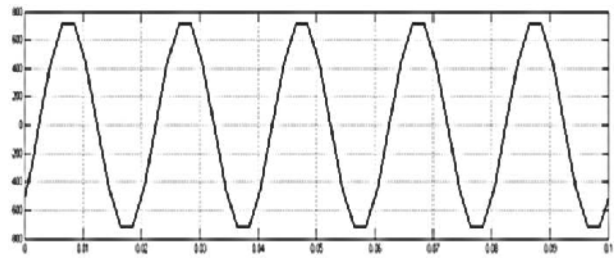

Fig. 5. Load Current.

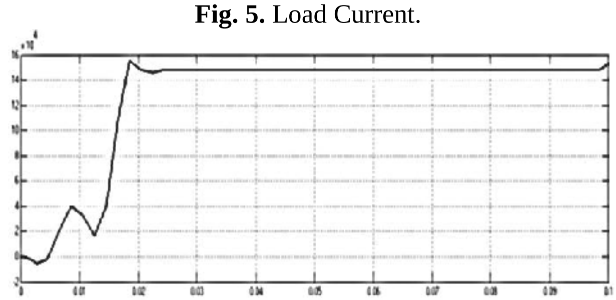

Fig. 6. Real Power.

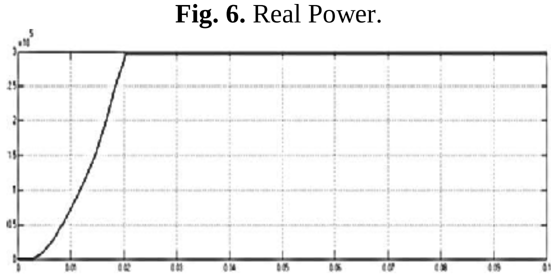

Fig. 7. Reactive Power.

The load voltage is found to be 0.945 kV, which is 15.5% below the required voltage. The real and reactive power profiles are also shown. So, in order to keep the system stable, we have to provide adequate compensation to the system. It is an established fact, that voltage stability is dependent on the reactive power. So, if we can improve the reactive power to meet the demand, then we can as well improve the voltage profile of the system to prevent it from dipping below the margin. In this paper, compensation using Fixed Capacitor, SVC and STATCOM are studied and compared to obtain the best compensation for the system under study.

III. COMPENSATION SYSTEM

A. STATCOM Compensated System

The SIMULINK model for a STATCOM compensated system is shown below:

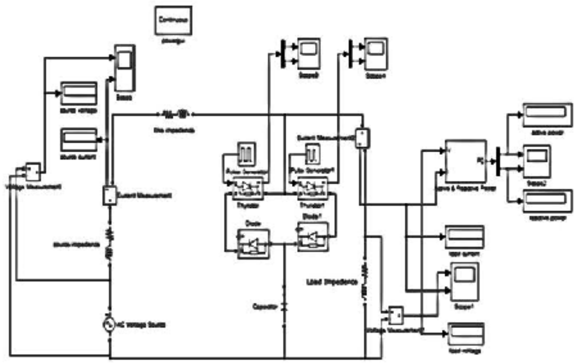

Fig. 8. STATCOM Compensated System.

The above figure shows the configuration of the STATCOM model connected to the system. The plots showing the improvement in the Load Voltage, Load Current and Real and Reactive Power are given below:

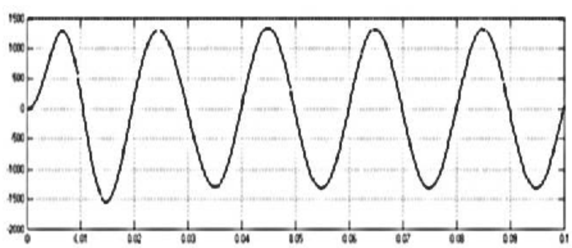

Fig. 9. Load Voltage.

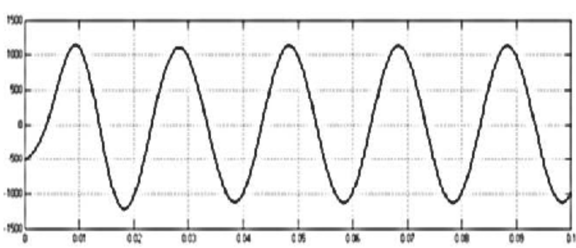

Fig. 10. Load Current.

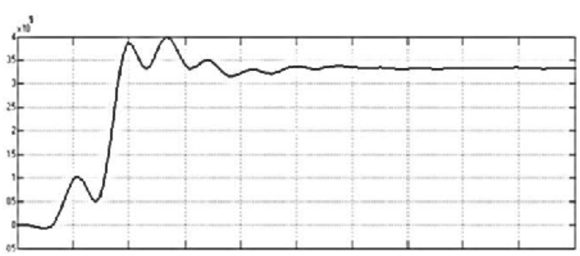

Fig. 11. Real Power.

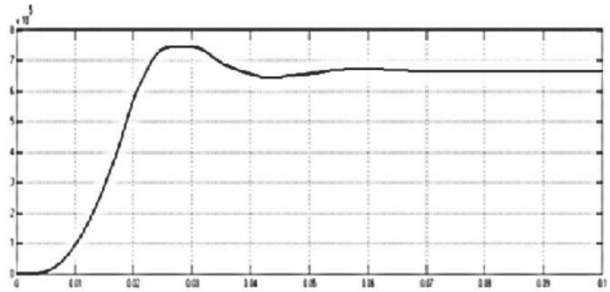

Fig. 12. Reactive Power.

Thus from the above figures, it is seen that there is considerable improvement in the real and reactive power flows as well as the receiving end voltage. For a capacitor value of 1200μF, the Real and Reactive Powers obtained are 0.3342MW and 0.7691MVAR respectively. The receiving end voltage is found to be 1.33kV for the present case. The voltage profile improves further with increased rating upto a certain point. The change in the power flows is obtained for different values of capacitance:

Table 1: Variation of Real and Reactive Power With the Variation of Capacitance.

Capacitance (μF)	Real Power (MW)	Reactive Power (MVar)
50	0.1533	0.3065
100	0.1581	0.3160
200	0.1683	0.3362
250	0.1736	0.3470
300	0.1793	0.3853
350	0.1851	0.3700
400	0.1912	0.3822
500	0.2043	0.4083
600	0.2186	0.4367
800	0.2508	0.5012
1000	0.2891	0.5774
1200	0.3342	0.6665

From the above table, it is seen that, both Real and Reactive power flows are improved impressively upto a capacitor rating of around 1200μF. Increasing the capacitance value further improves the power profile.

B. SSSC Compensated System

The SIMULINK model for a SVC compensated system is shown below:

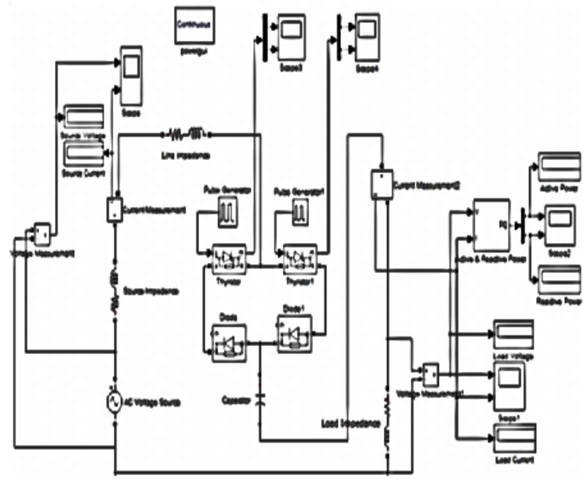

Fig. 13. SSSC Compensated System.

The above figure shows the configuration of the SSSC model connected to the system. The plots showing the improvement in the Load Voltage, Load Current and Real and Reactive Power are given below:

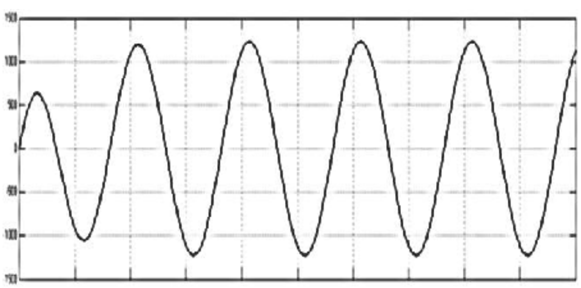

Fig. 14. Load Voltage.

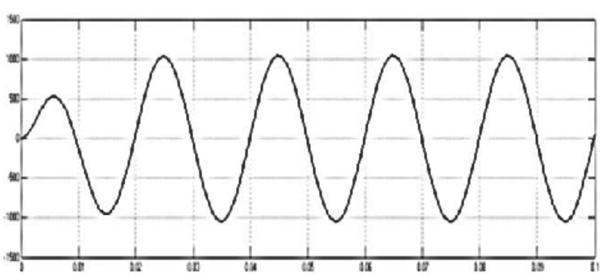

Fig. 15. Load Current.

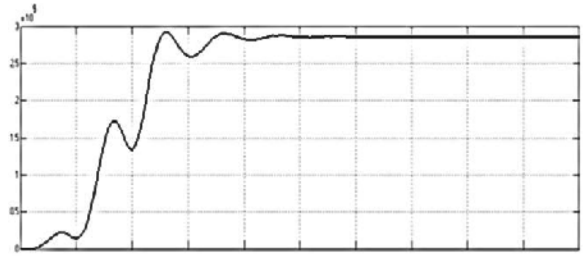

Fig. 16. Real Power.

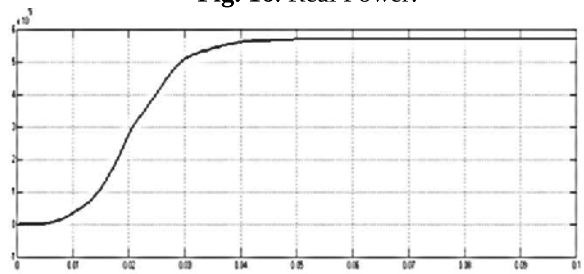

Fig. 17. Reactive Power.

Thus from the above figures, it is seen that there is considerable improvement in the real and reactive power flows as well as the receiving end voltage. For a capacitor value of 300μF, the Real and Reactive Powers obtained are 0.286MW and 0.5725MVar respectively. The change in the power flows is obtained for different values of capacitance:

Table 2: Variation of Real and Reactive Power with the Variation of Capacitance.

Capacitance (μF)	Real Power (MW)	Reactive Power (MVar)
50	.0107	.0214
100	.0547	.1097
200	.2203	.4417
250	.2699	.5410
300	.2860	.5721
350	.2831	.5673
400	.2746	.5492
500	.2533	.5073
600	.2362	.4720
800	.2132	.4264
1000	.1992	.3984
1200	.1901	.3673

From the above table, it is seen that, both Real and Reactive power flows are improved impressively upto a capacitor rating of around 300μF. Increasing the capacitance value further deteriorates the power profile.

C. UPFC Compensated System

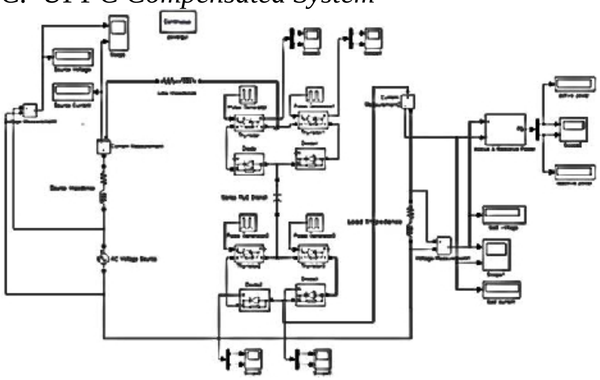

Fig. 18. UPFC Compensated System.

The above figure shows the configuration of the SSSC model connected to the system. The plots showing the improvement in the Load Voltage, Load Current and Real and Reactive Power are given below:

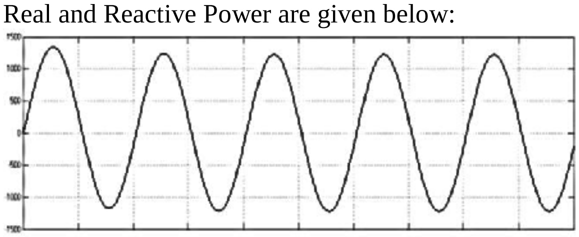

Fig. 19. Load Voltage.

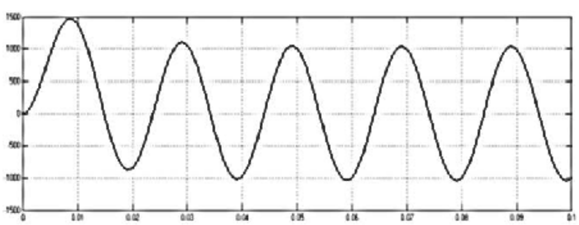

Fig. 20. Load Current.

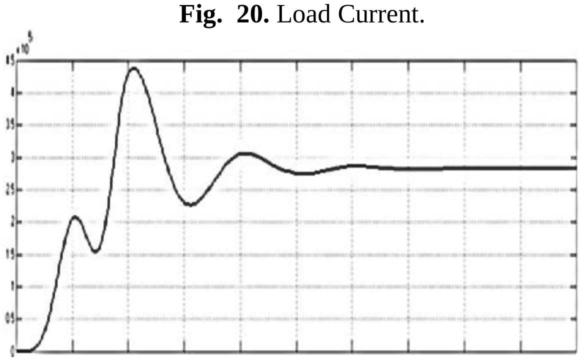

Fig. 21. Real Power.

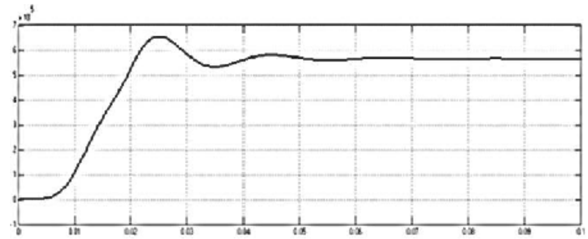

Fig. 22. Reactive Power.

Thus from the above figures, it is seen that there is considerable improvement in the real and reactive power flows as well as the receiving end voltage. For a capacitor value of 300μF, the Real and Reactive Powers obtained are 0.286MW and 0.572MVar respectively. The change in the power flows is obtained for different values of capacitance:

Table 3: Variation of Real and Reactive Power With the Variation of Capacitance.

Capacitance (μF)	Real Power (MW)	Reactive Power (MVAr)
50	.0107	.2143
100	.0547	.1097
200	.2203	.4417
250	.2699	.5410
300	.2860	.5721
350	.2831	.5673
400	.2746	.5492
500	.2533	.5073
600	.2362	.4720
800	.2132	.4264
1000	.1992	.3984
1200	.1901	.3802

From the above table, it is seen that, both Real and Reactive power flows are improved impressively upto a capacitor rating of around 300μF. Increasing the capacitance value further deteriorates the power profile.

IV. RESULTS AND CONCLUSION

Table 4: Comparison of power flow between above FACTS Devices.

FACTS Devices	Capacitance (μF)			
	300		1200	
	Real Power (MW)	Reactive Power (MVAr)	Real Power (MW)	Reactive Power (MVAr)
STATCOM	0.197	0.358	0.334	0.666
SSSC	0.286	0.572	0.199	0.380
UPFC	0.286	0.572	0.190	0.380

From the above table, it is seen that reactive power improvement will vary with change in capacitance in all the three cases. At a capacitor value of 300μF SSSC is seen to give best performance and at capacitor value 1200μF, STATCOM gives better performance. It is seen from the above simulation results that both the Power Flow and Voltage profiles are improved with all the compensating devices, but maximum real and reactive power compensation is obtained with the introduction of STATCOM in the system. STATCOM offers better performance in regulating the Voltage Stability of the system. But care has to be taken in determining the rating of the compensating devices in order to make the system stable as well as cost effective. In this paper, the variations in power and voltage profiles with controlled parameter variations have been presented. It will help in determining the appropriate capacitor and inductor values (as the case may be) for achieving optimum performance by the compensating devices.

REFERENCES

[1]. K.R. Padiyar, "FACTS controller in power transmission and distribution", New Age Int. Publisher, 2007.

[2]. CIGRE, FACTS Overview, *IEEE Power Engineering Society*, 95 TP.

[3]. Anulekha Saha, Priyanath Das, Ajoy Kumar Chakraborty,"Performance Analysis and Comparison of Various FACTS Devices in Power System", *International Journal of Computer Applications*, Vol. **46,** No.15, May 2012.

[4]. Bindeshwar Singh, K.S. Verma, Deependra Singh, C.N. Singh, Archana Singh, Ekta Agarwal, Rahul Dixit, Baljiv Tyagi, "Introduction of FACTS controllers, a critical review", *International Journal of reviews in computing*, Vol. **8**, 31st December 2011.

[5]. N.G Hingorani & Laszlo Gyugyi, "Understanding FACTS: concepts and technology of flexible AC transmission systems", *IEEE Press, New York* (2000).

[6]. Samima Akter, Anulekha Saha, Prof. Priyanath Das, "Modelling, Simulation and Comparision of various FACTS Devices in Power System", *International Journal of Engineering Research & Technology* (IJERT) Vol. **1**, 8th October – 2012.

[7]. Dr. B.R. Gupta & Er. Vandana Singhal, "*Power System Operation and Control*", S. Chand Publications.

[8]. D. Murali, Dr. M. Rajaram & N. Reka, "Comparison of FACTS Devices for Power System Stability Enhancement", *International Journal of Computer Applications*, Vol. **8**, No.4, October 2010.