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Power Quality improvement using UPFC

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ABSTRACT: Flexible AC transmission system (FACTS) devices uses power electronics components to maintain controllability and capability of electrical power system FACTS [1] controller includes unified power flow controller (UPFC), Static synchronous compensators (STATCOMs), Thyristor controlled series compensators (TCCs), Static series synchronous compensators (SSSCs) and Static VAR compensators (SVCs), are able to modify voltage, phase angle and impedance at particular bus in a power system. The (UPFC) is the most versatile and complex power electronic equipment that has emerged for the control and optimization of power flow in electrical power transmission system. This paper investigates the enhancement in voltage stability margin as well as the improvement in the power transfer capability in a power system with the incorporation of UPFC. A simple transmission line system is modeled in mat lab/Simulink environment. The load flow results are first obtained for an uncompensated system, and the voltage and power (real and reactive power) profiles are studied. The results so obtained are compared with the result obtained after compensating the system using UPFC to show the voltage stability margin enhancement. All the simulating for the above work have been carried out using matlab/Simulink software.

Keywords: FACTS, UPFC, STATCOM, SSSC.

I. INTRODUCTION

The unified power flow controller (UPFC) is one of the most widely used FACTs controllers and its main function is to control the voltage, phase angle and impedance of the power system thereby modulating the line reactance and controlling [2] the power flow in the transmission line The basic components of the UPFC are two voltage source inverters (VSIs) connected by a common dc storage capacitor which is connected to the power system through a coupling transformers. One (VSIs) is connected in shunt to the transmission system through a shunt transformer, while the other (VSIs) is connected in series to the transmission line through a series transformer. Three phase system voltage of controllable magnitude and phase angle (Vc) are inserted in series with the line to control active and reactive power flows in the transmission line [3]. So, this inverter will exchange active and reactive power within the line. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor (V_{dc}) constant. So, the net real power absorbed from the line by the UPFC is equal to the only losses of the inverters and the transformers [4].

The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point. The two VSI’s can work independently from each other by separating the dc side. So in that case, the shunt inverter is operating as a (STATCOM) that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. The series inverter is operating as (SSSC) that generates or absorbs reactive power to regulate the current flowing in the transmission line and hence regulate the power flows in the transmission line. The UPFC has many possible operating modes. (1) VAR control mode [5]. The reference input is a simple var request that is maintained by the control system regardless of bus voltage variation. (2) Automatic voltage control mode:- The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value with a defined slope characteristics the slope factor defines the per unit voltage error per unit of inverter reactive current within the current range of the inverter. In Particular, the shunt inverter is operating in such a way to inject a controllable [4] current into the transmission line.

The Fig. 1 shows how the (UPFC) is connected to the transmission line [6-7].

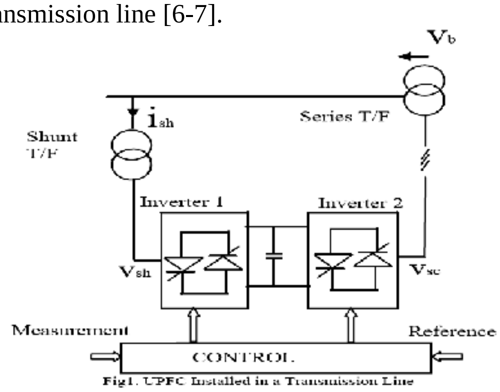

Fig. 1. Basic transmission (11kV, 50Hz).

II. MODEL OF AN UNCOMPENSATED SYSTEM

This model consists of different buses at which the simulation results were obtained by scopes. 11kv voltage is supplied from the AC voltage source to the system. Source resistance and inductances are 0.01Ω and 0.01H and load is kept constant at 30KW and 10KVAR for the above transmission line model. Simulation is done using MATLAB/SIMULINK

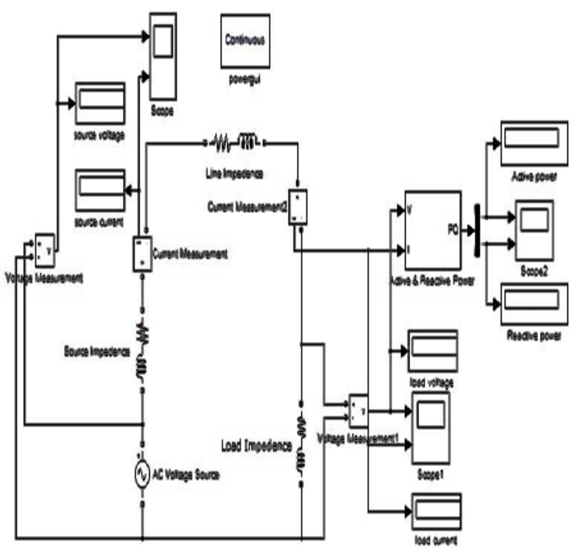

Fig. 2. Uncompensated system.

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:

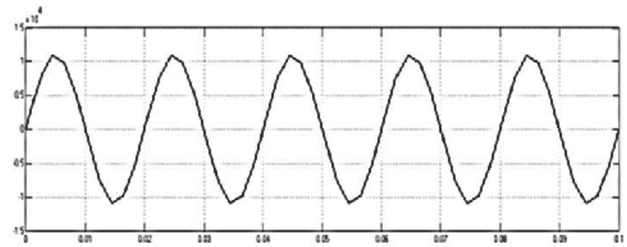

Fig. 3. Source Voltage.

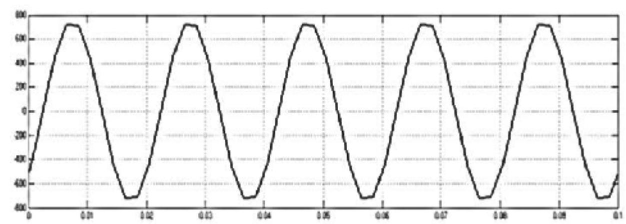

Fig. 4. Source Current.

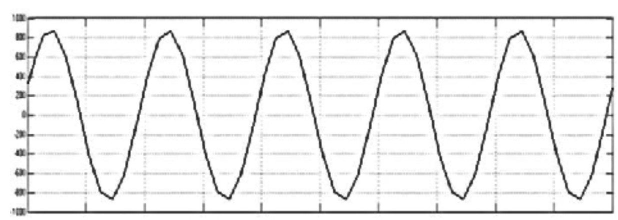

Fig. 5. Load Voltage.

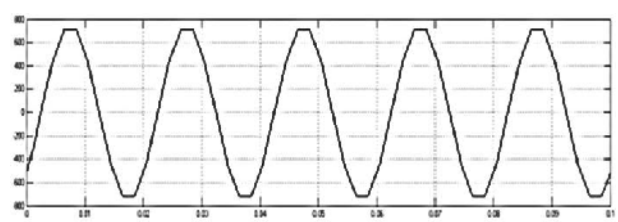

Fig. 6. Load Current.

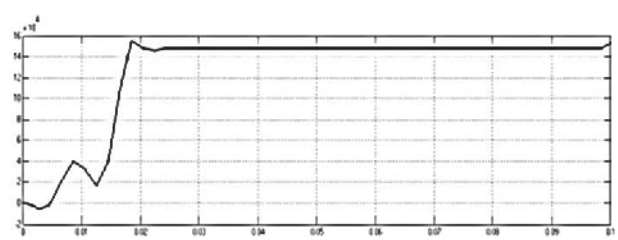

Fig. 7. Real Power.

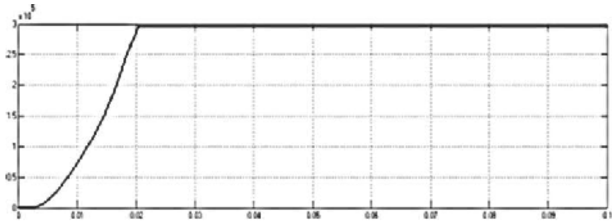

Fig. 8. Reactive Power.

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. UPFC COMPENSATED MODEL

The above circuit shows the basic model of UPFC connected to the system. This model is simulated using MATLAB. And we got the simulation results as shown below in Fig. 3.

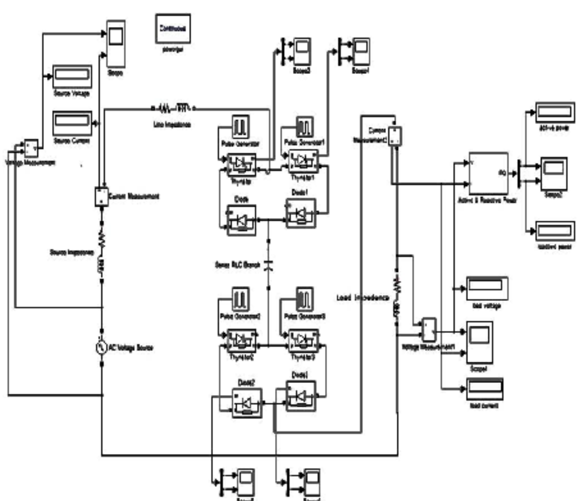

Fig. 9. UPFC Compensated system for voltage sag.

IV. RESULTS AND DISCUSSION

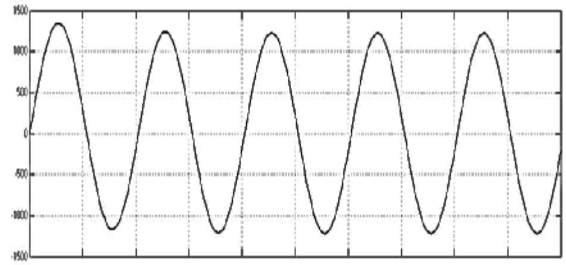

Fig. 10. Load Voltage.

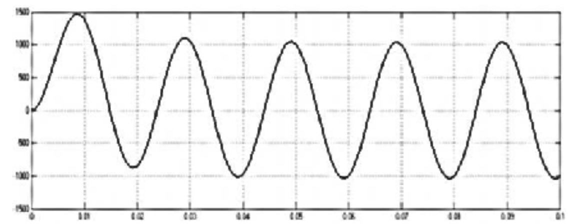

Fig. 11. Load Current.

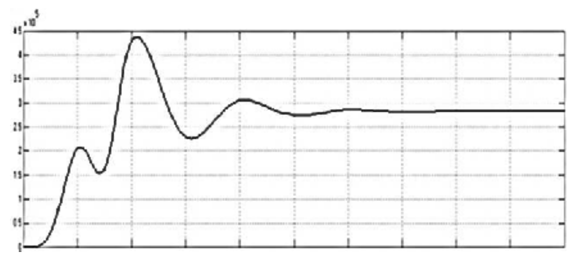

Fig. 12. Real Power.

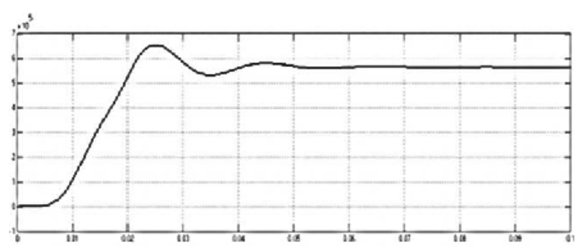

Fig. 13. Reactive Power.

The above graphs show real, reactive and receiving end voltage improvement using compensation. Graphs obtained for a particular value of capacitor rating (350uF) are shown above. Power flows obtained with change in capacitance are tabulated below

Table 1: Variation of power flow with change in 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

Comparison between other FACTS devices.

FACTS Devices	Capacitance (μF)			
	300		1200	
	Real Power (MW)	Reactive Power (MVAr)	Real Power (MW)	Reactive Power (MVAr)
STATCOM	0.1973	0.3583	0.3342	0.6665
FC-TCR	0.1678	0.3358	0.3102	0.6205
SSSC	0.2862	0.5725	0.1902	0.3804
UPFC	0.2862	0.5721	0.1901	0.3802

From the above table, it is seen that both power flow is improved up to a certain limit of capacitance (350μF). In this point injection of real and reactive power in the system is maximum. Beyond this, if we increase the value of capacitance then power profile starts deteriorating. So, we can conclude that desirable performance is obtained at capacitor rating 300μF for UPFC compensated system.

V. CONCLUSION

From the above simulation we conclude that SVC is able to compensate the voltage sag as well as voltage swell. It also increases the power transmission capability. The simulation results indicated a considerable increase in power flow limit by SVC compensation. Further study on impacts of various FACTS controllers such as UPFC, STATCOM, etc. should be carried out to seek for the most effective way of increasing the power flow limit.

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