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Performance Analysis of Different Types of Facts Controllers in a Transmission Line

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ABSTRACT: Unified power flow controller (UPFC) is used to control the power in the transmission systems by controlling the impedance, voltage magnitude and phase. The basic structure of UPFC consists of two voltage source converters (VSI), where one converter is connected in parallel to the transmission line (STATCOM) while the other is in series with the transmission line (SSSC). The aim of the paper is the modeling, the identification of the reference and control of UPFC and studying its influence on the electrical network. Finally the simulation results have been presented to indicate the improvements in the performance of the UPFC to control the voltage in the power system UPFC can control the real and reactive power flow in the transmission system. Basically this paper shows the result that shows the performance of the system for each of the facts devices in improving the power flow in the transmission lines. All the simulations are carried out by using MATLAB/SIMULINK software. The simulation result shows the performance of facts devices in a transmission lines.

Keywords: FACTS, FCTCR, real and reactive power, STATCOM, TCSC, UPFC

I. INTRODUCTION

Today power systems are highly complex and require careful design of new devices taking into consideration the already existing equipment especially for the transmission systems in a new deregulated electricity markets. In the late 1980s the EPRI (electric power research institute) introduced a new approach to solve the problem of designing and operating power system the proposed concept is known as flexible AC transmission systems (facts).The two main objectives of FACTS is to increase the transmission capacity and control the power flow over designated transmission routes. The UPFC is the most versatile and complex of the facts devices, combining the features of the STATCOM and SSSC .the UPFC can provide simultaneous control of the basic power system parameters like transmission voltage, impedance and phase angle. It is recognized as the most sophisticated power flow controller currently and probably the most expensive one. A UPFC control system that includes both the converter and the series converter has been simulated. The performance of the UPFC in real and reactive power flow through the transmission line has been evaluated. Facts controllers includes (STATCOM)Static synchronous compensator, Thyristor controlled series capacitor(TCSC),Static series synchronous compensator(SSSC),which are capable of controlling the network condition in a very fast manner to improve voltage stability and power quality.

II. BRIEF LITERATURE REVIEW

IN [2] For power quality improvement how facts devices are used and how to improve the power system operation have been studied in [3], static voltage stability margin enhancement by the effect of SVC and STATCOM is studied. In [4] various types of facts controller and their performance characteristics have been described. In [5] simulation and comparison of various facts devices FC-TCR, UPFC using PSPICE software has been done. In [6] modeling and simulation of SSSC multi machines systems for power system stability enhancement is studied. In [7] how to improve steady state stability by placing SSVC at different places has been discussed. In [8], use of facts controllers for the improvement of transient stability have been studied. In [9], using MATLAB/SIMULIMK software simulation is done to demonstrate the performance of the systems for each of the facts devices e.g. FCTCR, STATCOM, TCSC, SSSC and UPFC in improving the power profile and thereby the voltage stability of the same. In [10], using MATLAB/SIMULINK software performance of the shunt capacitor, FC-TCR and STATCOM has been discussed, in this paper modeling and simulation of various facts devices FC-TCR, STATCOM, TCSC and UPFC have been done using MATLAB/SIMULINK software by varying the capacitance value line impedance is controlled and the real and reactive power is measured.

III. BASIC DESCRIPTION OF FACTS CONTROLLER

A. Fixed Capacitor Thyristor Controlled Reactor(FC-TCR)

FC-TCR fixed capacitor Thyristor controlled reactor-Static Var systems are used in the transmission lines for rapid control of voltage at weak point in the static Var compensators(svc) are shunt connected static generated/absorbers whose outputs are varied to control voltage of the power system. The use of svc in transmission line is to provide high performance in steady state and transient voltage stability control, to dampen power swing, to reduce system loss and to control real and reactive power flow .FC-TCR type SVC is shown in figure 1. In FC-TCR a, capacitor is connected in parallel with a Thyristor controlled reactor. The fixed capacitor is substituted fully or partially by a filter network that has the capacitive impedance at the fundamental frequency to generate the reactive power .In FC-TCR type Var generator consists of a variable reactor and the reactor current is varied by the method of firing delay angle control. The reactor current is increased by decreasing the delay angle alpha to decrease the capacitive output when the capacitive and inductive currents becomes equal ,both the Var cancel out and gives zero Var output with further decrease in angle alpha the inductive current becomes lower than the capacitive current and gives inductive output.

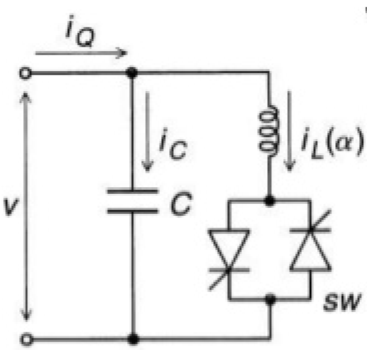


Fig. 1. Fixed capacitor Thyristor controlled reactor [1].

B. Static Synchronous Compensator (STATCOM)

The STATCOM is a shunt connected reactive power compensation device that is capable of generating and or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system .specifically, the STATCOM is a voltage source converter that from a given input of dc voltage produces a set of 3 phase ac output voltages each in phase and with coupled to the corresponding ac system voltage through a relatively small reactance. The dc voltage is provided by an energy storage capacitor.

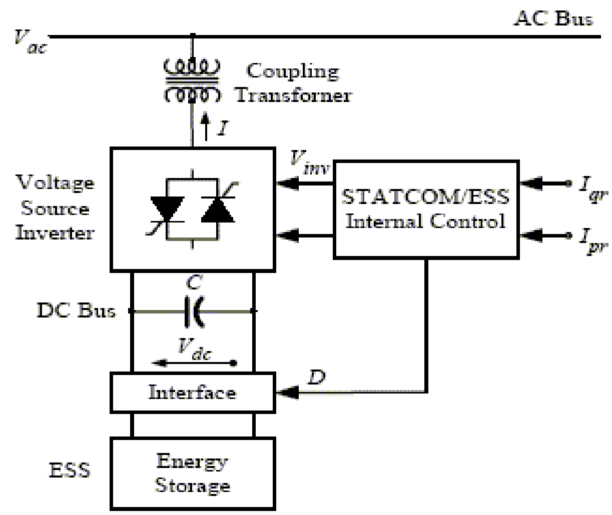


Fig. 2. Static synchronous compensator [1].

*C. Thyristor Controlled Series Capacitor (**TCSC**)*

In TCSC a variable Thyristor controlled Reactor is connected across a series capacitor. When the firing angle of the TCR is 180 degrees, the reactor becomes none conducting and the series capacitor has the normal impedance. As the firing angle is decreased below 180 degree the capacitive reactance increases. When the firing angle is 90 degrees, the reactor becomes fully conducting and the total impedance becomes inductive. With the 90 degree firing angle, the TCSC helps in limiting fault current. Thyristor controlled series capacitor can be used for several power system performance enhancements and is connected in series with the transmission line .The main applications are-

a) Reduction of voltage fluctuations with specified limits during changing power transmissions.
b) Limitations of short circuit currents in networks or substations.
c) To reduce the sub synchronous resonance (SSR) problem.
d) The prevention of voltage collapse.

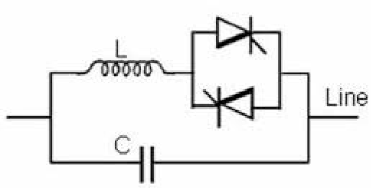


Fig. 3. Thyristor Controlled Series capacitor (TCSC) [1].

D. Unified Power Flow Controller (UPFC)

It is based on the back to back voltage source converter arrangement in which one converter is in series and the other is in shunt with the transmission line and both the converters are operated from a common dc link provided by a dc storage capacitor. This arrangement functions as an ideal ac to ac power converter in which the real power can freely flow in either direction between the ac terminals of the two converters each converter can independently generates or absorbs reactive power at its own ac output terminal .The function of converter 1 is to supply or absorb the real power demanded by converter 2 at the common dc link to support the real power exchange resulting from the series voltage injection .The dc link demand of converter 2 at the common dc link to support the real power exchange resulting from the series voltage injection. The dc link power demand of converter is converted back to ac by converter 1 and coupled to the transmission line by shunt connected transformer .converter 1 can also generate and absorb controllable reactive power to provide independent shunt reactive compensation for the line . The UPFC primarily injects a voltage in series with the line whose phase angle can vary between 0 to 2π with respect to the terminal voltage and whose magnitude can be varied from 0 to defined maximum value. 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 constant so, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers .The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so as to provide a voltage regulation at the connection point .The two converters can work independently of 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 current flow, and hence the power flow in a transmission line.

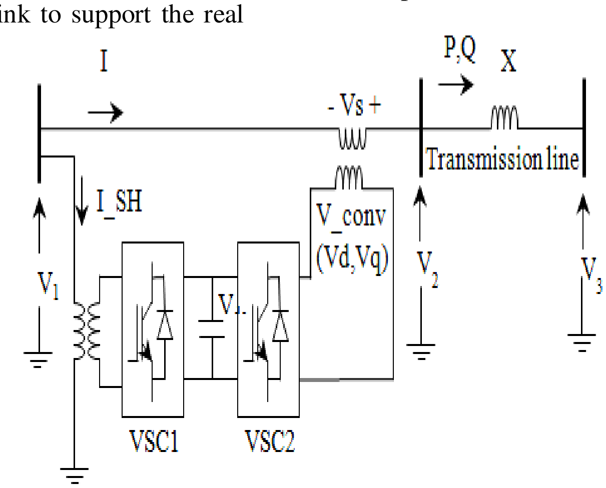


Fig. 4. Unified Power Flow Controller [1].

Objective

The main objective of this paper is to implement facts devices in a transmission line for dynamic reactive power compensation to increase the line capacity.

IV. DESCRIPTION OF THE SYSTEM

A Basic transmission (11kv) model has been employed in MATLAB /SIMULINK program to study about the facts devices in detail. A single line diagram of the sample power transmission system is shown in figure 5.

11 KV voltage is supplied from the ac voltage source to the system. The transmission line is considered to be a short transmission line hence capacitance of the line is neglected the resistance of the line is 5 ohm and the inductance is 0.06mh the source impedance is (0.01+0.001) ohm and the load is kept constant at 25 MW and 50 MVAR the current and voltage measurement blocks are used to measure the voltage and current at source by the use of active and reactive power measurement block the real and reactive power in the load is measured.

V. SIMULATION AND RESULTS

A. Uncompensated model

The SIMULINK model of uncompensated system is shown below.

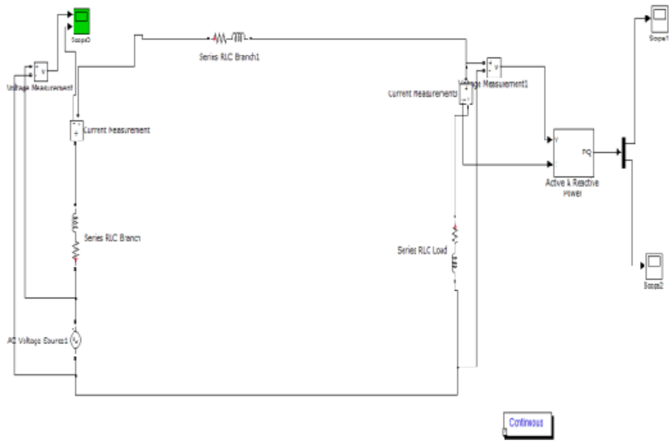


Fig. 5. Uncompensated system.

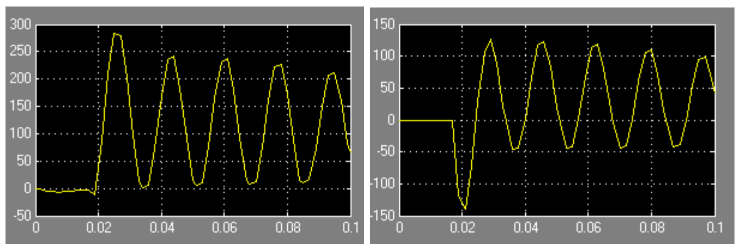


Fig. 6. Real and reactive power flow *FC*.

B. TCR Compensated System

The SIMULINK model of FC-TCR Compensated system is shown below

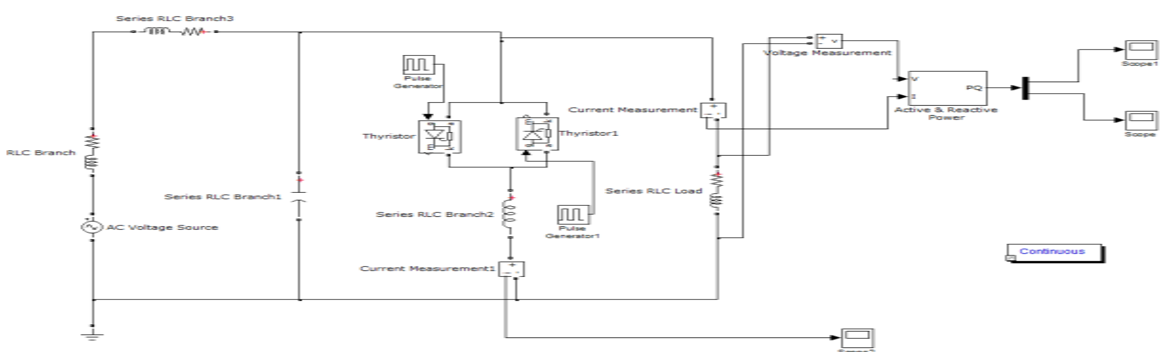


Fig. 7. FC-TCR Compensated system.

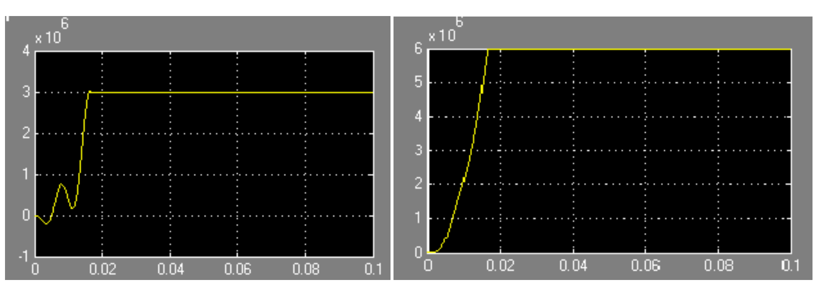


Fig. 8. Real and reactive power flow.

Table 1: Variation of power Flow with change in capacitance.

SNO	CAPACITANCE(MICRO FARAD)	REAL POWER(MW)	REACTIVE POWER(MVAR)
1	50	1.55	3.1
2	100	1.62	3.25
3	600	2.49	5
4	800	2.8	5.6

From the above table shown that power flow through the system increases with the increase in capacitance

C. STATCOM Compensated system

The SIMULINK model of STATCOM compensated system is shown below

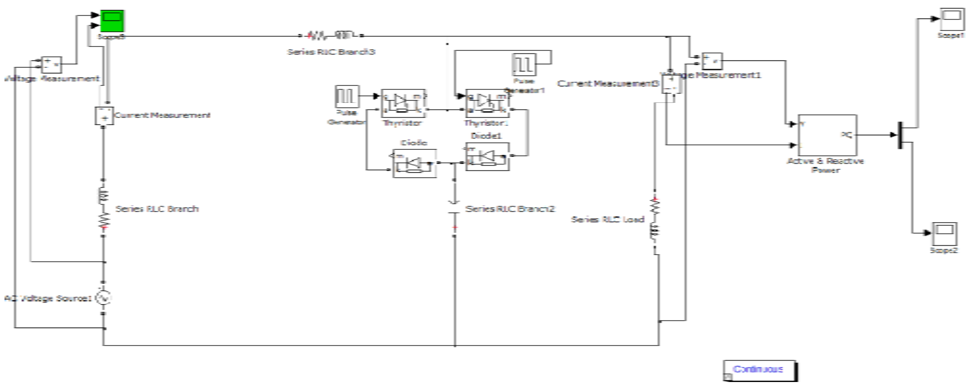


Fig. 9. STATCOM compensated system.

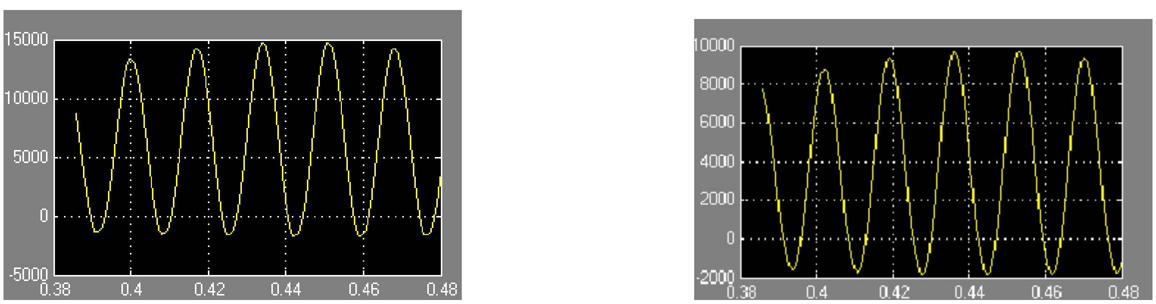


Fig.10. Real and reactive power flow.

Table 2: Variation of power Flow with change in capacitance.

SNO	CAPACITANCE	REAL POWER(MW)	REACTIVE POWER(MVAR)
1	20	0.0145	0.0094
2	50	0.0146	0.0095
3	100	0.0147	0.0097
4	200	0.0146	0.0096
5	300	0.0143	0.0092

From the above table it is seen that both active and reactive power increases with the increase in capacitance value up to 100µF.. Beyond this value both real and reactive power starts decreasing. So the better compensation is obtained at a capacitor value of 200µF.

D. TCSC Compensated System

The SIMULINK model of TCSC Compensated system is shown below.

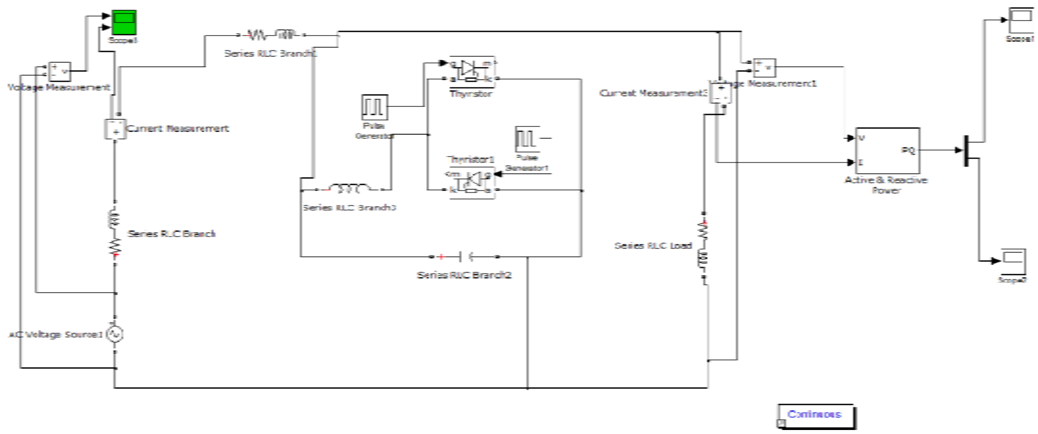


Fig. 11. TCSC compensated system.

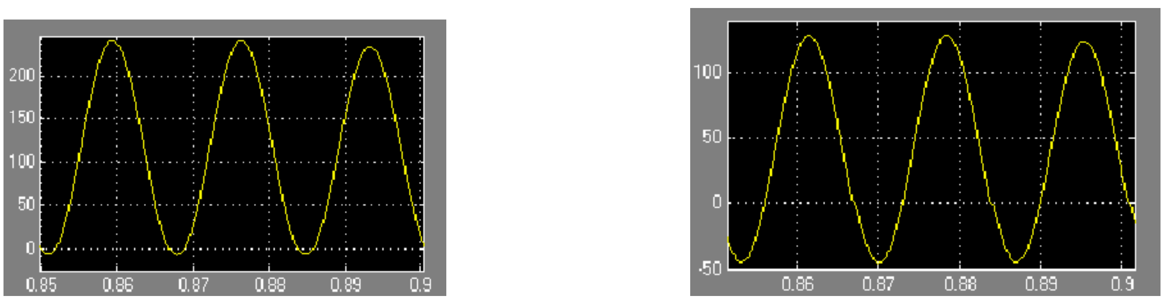


Fig. 12. Real and reactive power flow.

Table 3: Variation of power Flow with change in capacitance.

SNO	CAPACITANCE(MICRO FARAD)	REAL POWER(MW)	REACTIVE POWER(MVAR)
1	20	241	127.7
2	30	241.3	128
3	40	241	127.7
4	50	240.4	127.37
5	100	238.7	125
6	200	230	117

From the above table it is seen that both active and reactive power increases with the increase in capacitance value up to 30µF. Beyond this value both real and reactive power starts decreasing. So the better compensation is obtained at a capacitor value of 30µF.

E. UPFC Compensated system

The SIMULINK model of UPFC compensated system is shown below

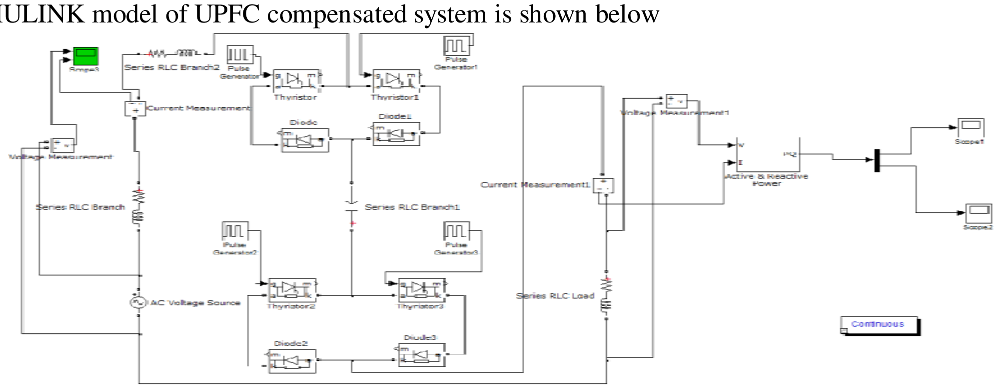
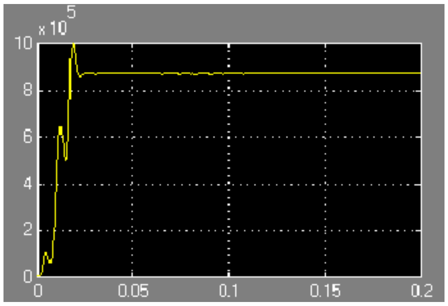


Fig.13. UPFC compensated system.



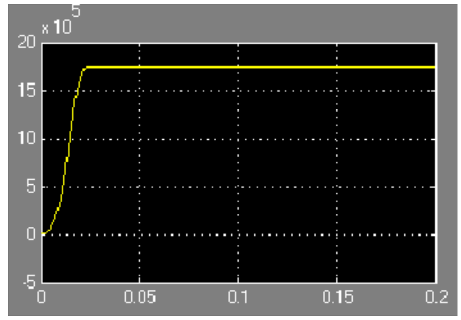


Fig.14. Real and Reactive power flow.

Table 4: Variation of power Flow with change in capacitance.

SNO	CAPACITANCE(MICRO FARAD)	REAL POWER(MW)	REACTIVE POWER(MVAR)
1	50	0.022	0.044
2	100	0.091	0.184
3	200	0.358	0.72
4	250	0.53	1.06
5	350	0.87	1.74
6	400	1.01	2

From the above table it is seen that power flow through the system increases with the increase in capacitance.

VI. CONCLUSION

MATLAB/SIMULINK environment is used for this comparative study using 11 KV simple transmission line .This paper presents performance analysis of FC-TCR, STATCOM, TCSC and UPFC facts devices in graphical form .real and reactive power flow profile are seen to improve with all the compensating devices. .UPFC provides better compensation in comparison to other facts devices. Results show that in case of FC-TCR compensation, reactive power flow improves proportionally with increasing capacitance and is maximum at maximum value of capacitance (1000µF here). In case of STATCOM compensation a capacitor rating 100µF yield best result. For TCSC compensation with a fixed inductance of 100mH and capacitance value of 30µF gives best result. For UPFC compensation Reactive power improves proportionally with increasing capacitance and is maximum at maximum value of capacitance (450µF here). In our various schemes FCTCR type SVC provides compensation from a capacitor value as low as 50 µF and it further improves at higher value of capacitance without disturbing the stability.

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