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Investigation of FACTS Controller

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ABSTRACT

For improving the dynamic performance of modern power and transmission systems, Flexible AC Transmission Systems (FACTS) devices have been used since 1970s. FACTS devices use power electronic components for improvement and development of system performance. The FACTS controller includes the Fixed Capacitor Thyristor Controlled Reactor (FC_TCR), Static Synchronous Compensator (STATCOM), Thyristor Controlled Series Compensator (TCSC), Static Series Synchronous Compensator (SSSC), Static VAR Compensator (SVC) and the Unified Power Flow Controller (UPFC), which are used in the transmission and distribution systems to improve power transfer capability and to enhance the power system stability. UPFC can independently control both the real and reactive power flow in the line. This paper shows the performance of the system for each of the FACTS devices in improving the power flow and minimizing the losses in the transmission line. All the simulations are carried out with the MATLAB/SIMULINK software. The conclusion shows the performance of FACTS devices and the improvements for the power stability in transmission lines.

I. INTRODUCTION

To provide affordable electricity, present power system is exempt, under which power is produced by distinct generation, transmission and distribution systems. FACTS is defined by IEEE as "a power electronics based system and other static equipment that provides control of one or more AC transmission systems' parameters to enhance control and improve power transfer ability". FACTS enhances the reliability of AC grids and decreases power delivery costs. They improve transmission quality and efficiency of power transmission by providing inductive or reactive power to grid. Electric power demand is rising day by day. Thus it is essential to work on utilizing the existing generating units and to load the existing transmission line to their thermal limits and to maintain stability of voltage. It is also required to operate power systems with the least loss in the transmission line. Flexible AC Transmission System (FACTS) devices play animportant role in controlling power and improving the usable capacity of existing lines. The upcoming electric transmission systems can be smart and reliable by using FACTS devices.

FACTS controller contains Static Synchronous Compensator (STATCOM), Thyristor Controlled Series Capacitor (TCSC), Static Series Synchronous Compensator (SSSC), Static VAR Compensator (SVC), which are capable of controlling the network form in a fast way to advance voltage stability and power quality. Reactive power imbalance occurs when the system is faulted, heavily loaded and voltage fluctuation is there. Reactive power balance can be complete by using FACTS devices in the transmission line, which can inject or absorb reactive power in the system as per requirement.

II. BRIEF LITERATURE REVIEW

These days, voltage collapse is a problem in power systems which occurs due to the voltage instability. Research is currently being done to find new ideas for minimising voltage collapse by increasing voltage stability. There is a limited set of analysis methods for decisive voltage stability of power system. In [4], the

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ability of a power system and how to control for small disturbances e.g.:- change in load, has been discussed. In [7], for power quality improvement, how FACTS devices are used and how to improve power system operation have been discussed. In [10], static voltage stability margin enhancement by the effect of SVC and STATCOM have beendiscussed. In [11], various types of FACTS controllers and their performance characteristics have been described. In [12], simulation and comparison of various FACTS devices (FC-TCR, UPFC) using PSPICE software has been done. In [14], modelling and simulation of SSSC multi machine system for power system stability enhancement is described. In [15], improvement of steady state stability by placing SVC at different places has been discussed. In [19], Use of FACTS controllers for the improvement of transient stability has been described.

In [20], MATLAB/SIMULINK software simulation is done to validate the performance of the system for each of the FACTS devices e.g. FC-TCR, STATCOM, TCSC, SSSC AND UPFC in improving the power profile and there by voltage stability of the same. In [21], using MATLAB/SIMULINK software performance of shunt capacitor, FC-TCR and STATCOM has been discussed. In this paper modelling and simulation of several FACTS devices (FC-TCR, STATCOM, TCSC and UPFC) have been done using MATLAB/SIMULINK software. By changing the capacitance value line impedance is controlled and real and reactive power is measured.

III. BASICS OF FACTS CONTROLLER

(A) Fixed Capacitor Thyristor Controlled Reactor (FCTCR)

Static var systems are used in transmission lines for the quick control of voltage at weak points in a network. Static var Compensators (SVC) are shunt connected static generator/absorbers whose outputs are varied to control voltage of the power system. The use of SVC in transmission line is to deliver 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.

In FC-TCR, a capacitor is connected in parallel with a Thyristor Control 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 α to decrease the capacitive output. When the capacitive and inductive currents become equal, both the vars cancel out and gives zero var output. With further reduction in angle α, the inductive current becomes superiorto the capacitive current and gives inductive output.

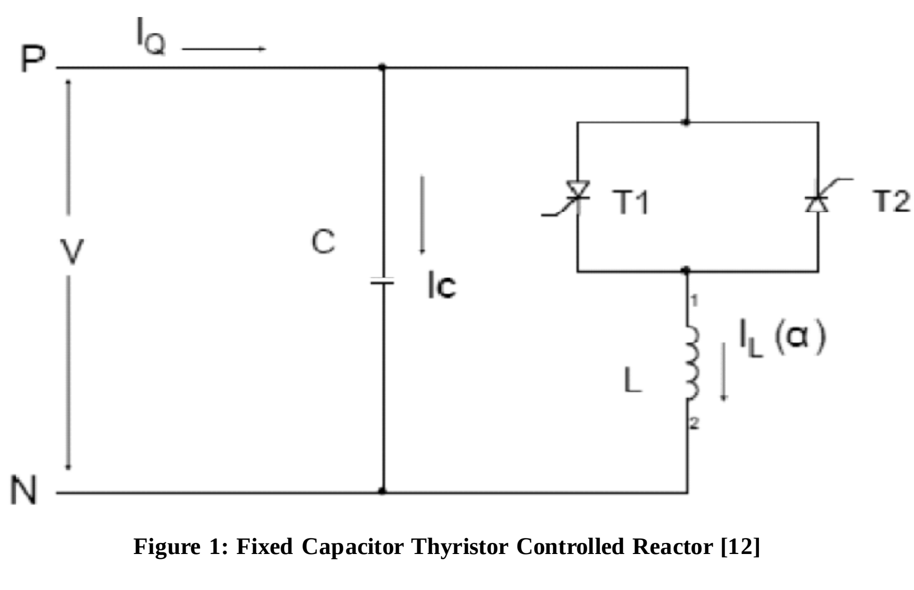

Figure 1: Fixed Capacitor Thyristor Controlled Reactor [12]

(B) Static Synchronous Compensator (STATCOM)

STATCOM is a shunt connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage. Fig. 2 shows a simple one line diagram of STATCOM based on a voltage source converter.

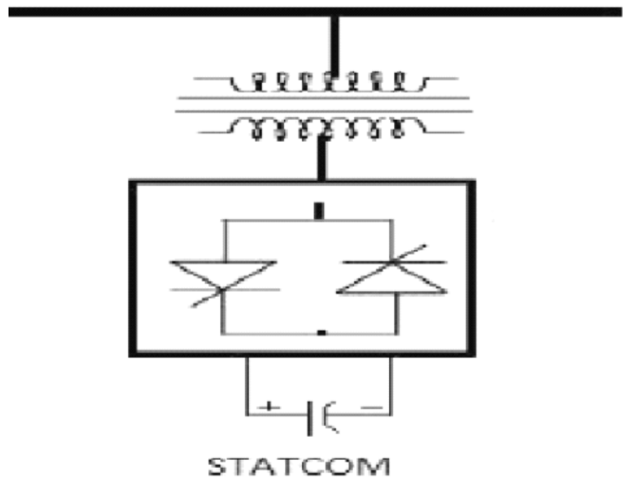

Figure 2: Static Synchronous Compensator [20]

The voltage source converter converts dc voltage to ac voltage by using GTO and the ac voltage is injected into the line through the transformer. If the output of the VSC is more than the line voltage, the converter supplies lagging var to the transmission line. If the line voltage is more than the converter output voltage then the converter absorbs lagging var from the system.

(C) Thyristor Controlled Series Capacitor (TCSC)

Thyristor Controlled Series Capacitor is a series compensated FACTS device which consists of a series capacitor bank shunted by a thyristor controlled reactor in order to provide a smoothly variable series capacitive reactance. Fig. 3 shows a single line diagram of TCSC controller.

The TCSC is based on the thyristor without gate turn-off capability. 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 non-conducting and the series capacitor has the normal impedance. As the firing angle is decreased below 180 degrees 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 degrees firing angle, The TCSC helps in limiting fault current.

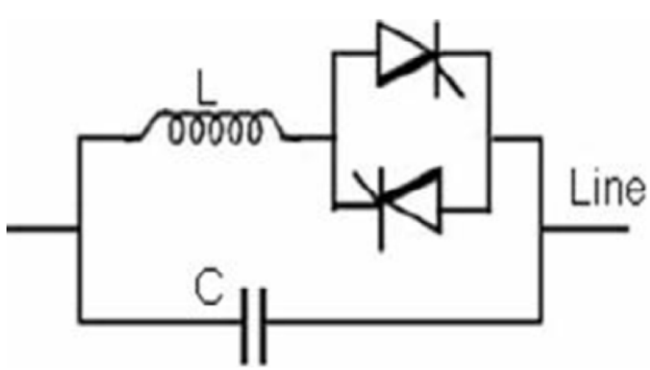

Figure 3: Thyristors Controlled Series Capacitor (TCSC) [20]

(D) Unified Power Flow Controller (UPFC)

UPFC is a multifunctional FACTS device, which has a multi-usage compensation capability. UPFC is based on the back-to-back voltage source converter arrangement in which one converter is in series and the other is in parallel 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 generate or absorb reactive power at its own AC output terminal.

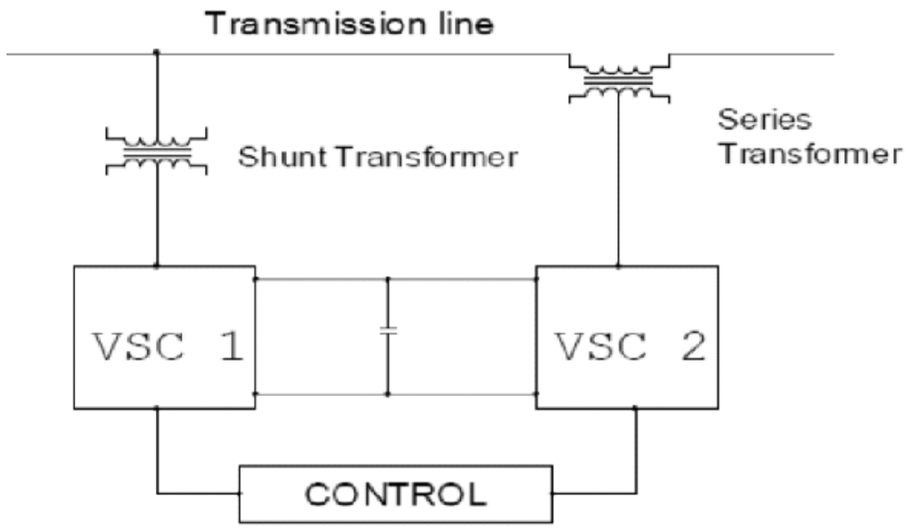

Figure 4: Unified Power Flow Controller (UPFC) [12]

Figure [4] shows the schematic diagram of UPFC. 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 power demand of converter 2 is converted back to AC by converter 1 and coupled to the transmission line via a shunt connected transformer. Converter 1 can also generate or absorb controllable reactive power to provide independent shunt reactive compensation for the line. The UPFC can be operated for reactive shunt compensation, series compensation and phase angle regulation to meet multiple control objectives. 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 the defined maximum value.

IV. 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.

V. 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 Fig. 5. 11KV voltage is supplied from the AC voltage source to the system. The transmission line is considered to be a short transmission line,which is why the capacitance of the line is neglected. The resistance of the line is 5&! and the inductance is 0.06mH. The source impedance is (0.01+0.001) &! and the load is kept constant at 25MW and 50MVAR .The current and voltage measurement blocks are used to measure the voltage and current at the source. By the use of the Active and Reactive Power Measurement Block, the real and reactive power in the load is measured.

VI. SIMULATION RESULTS

(A) Uncompensated model

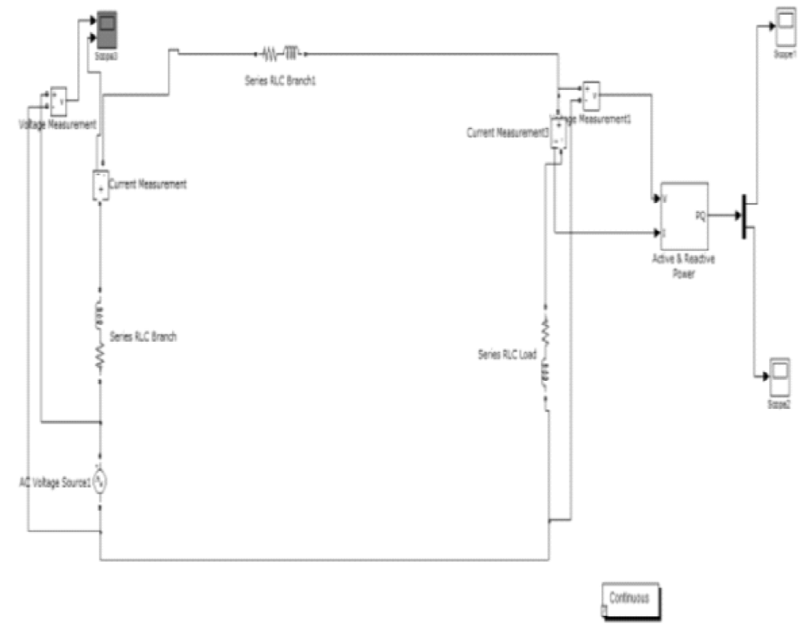

Figure 5: Uncompensated System

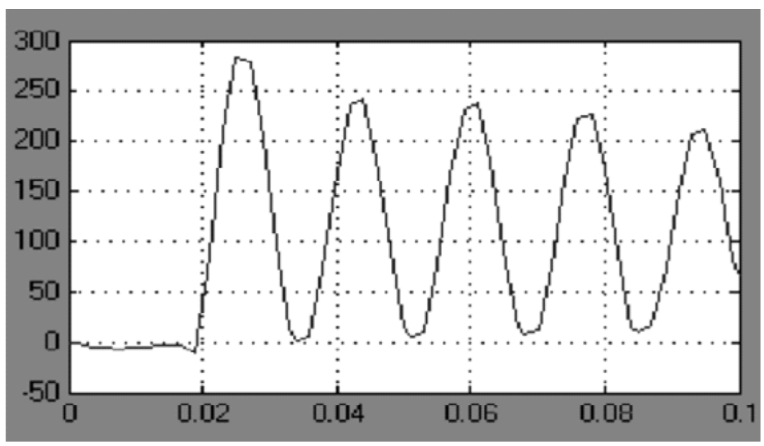

Figure 6: Real Power Flow

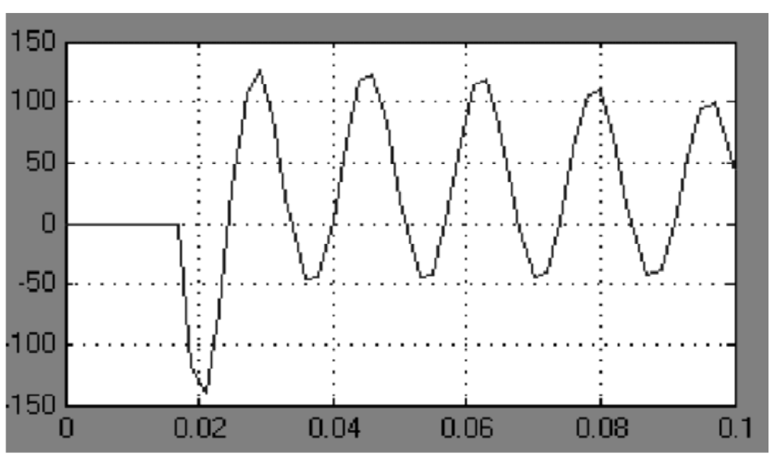

Figure 7: Reactive Power Flow

(B) FC-TCR Compensated System.

The SIMULINK model of FC-TCR is shown below.

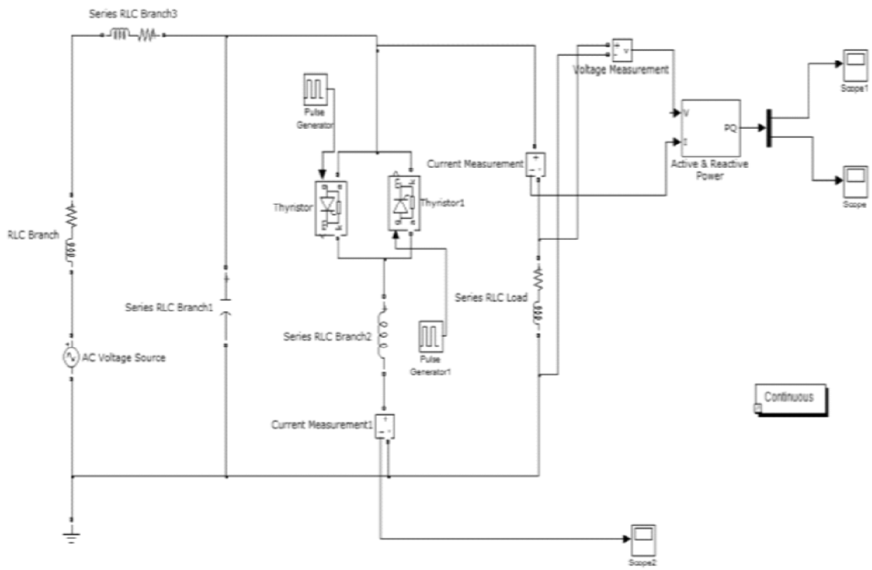

Figure 8: FC-TCR compensated system

Results obtained after simulation is shown below.

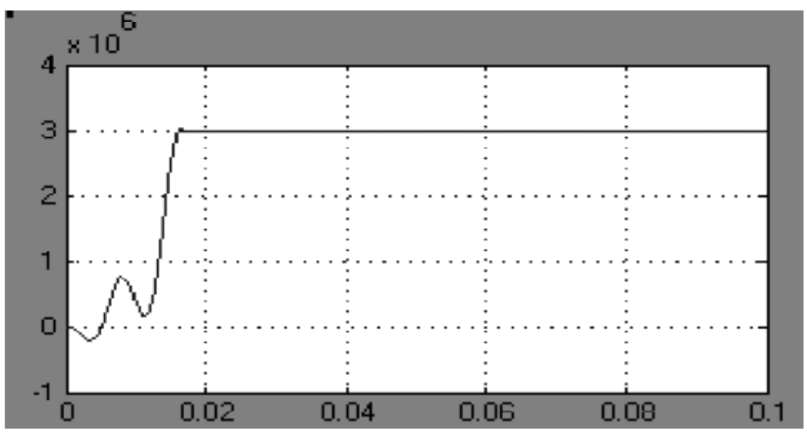

Figure 9: Real Power Flow

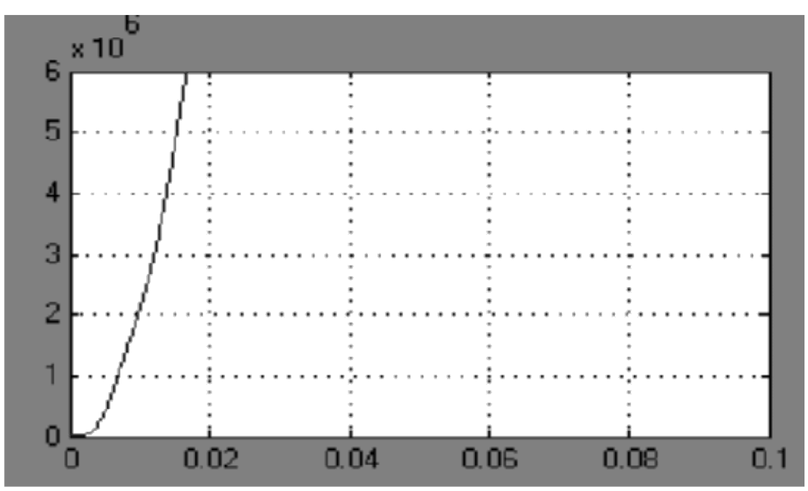

Figure10: Reactive Power Flow

Table 1
Variation of Power Flow with Change in Capacitance

S.no	*Capacitance*	*Real Power*	*Reactive Power*
1	50	1.55	3.1
2	100	1.62	3.25
3	150	1.7	3.4
4	200	1.76	3.57
5	300	1.95	3.9
6	400	2.13	4.25
7	500	2.31	4.62

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

(A) STATCOM Compensated System

The SIMULINK model of STATCOM compensated system is shown below

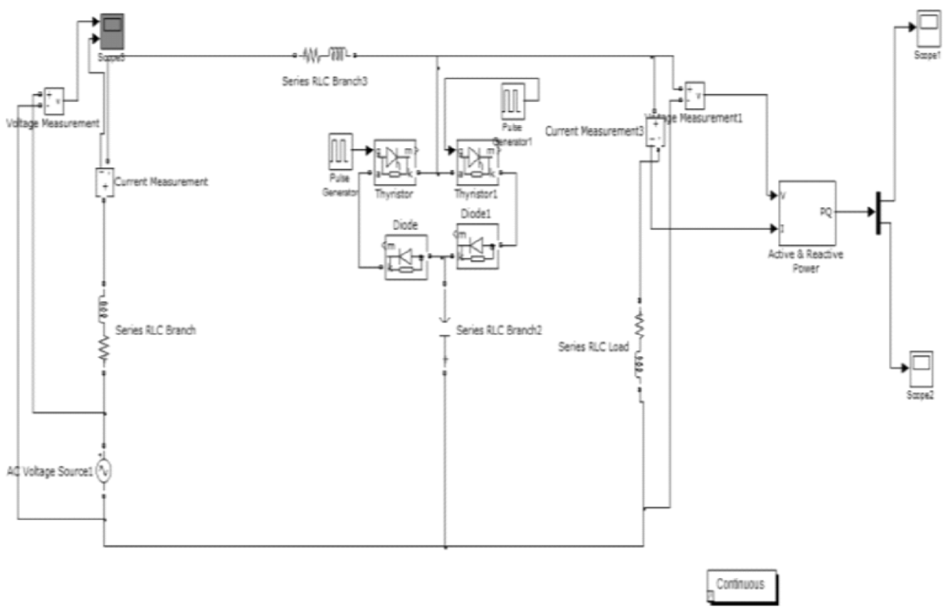

Figure11: STATCOM compensated system

Results obtained after simulation is shown below.

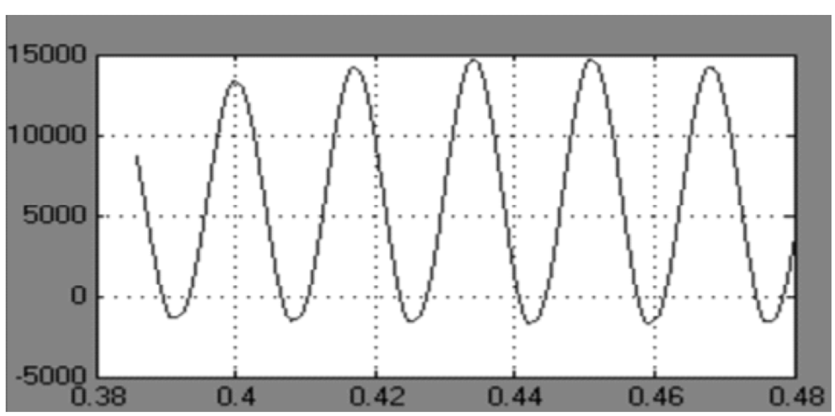

Figure 12: Real Power Flow

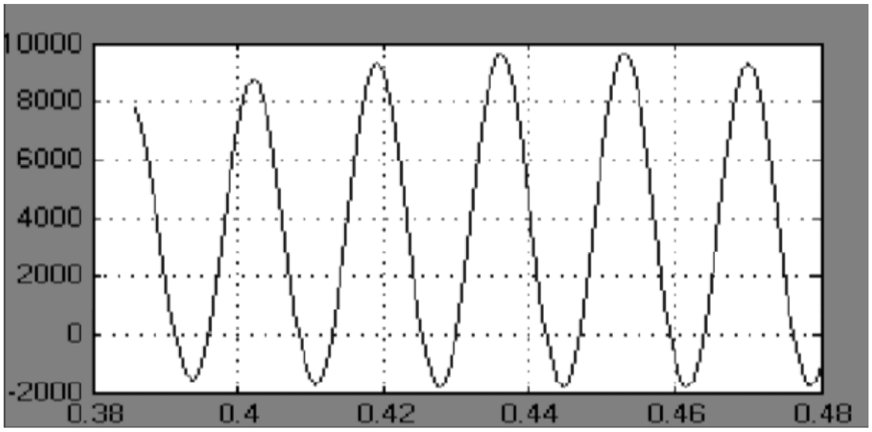

Figure 13: Reactive Power Flow

Table 2
Variation of Power Flow with Change in Capacitance

S.no	*Capacitance*	*Real Power*	*Reactive Power*
1	20	0.0143	0.0094
2	50	0.0145	0.0095
3	100	0.0147	0.0097
4	200	0.0146	0.0096
5	300	0.0143	0.0092
6	400	0.0137	0.0083
7	500	0.0130	0.0078

From the table shown above, it is seen that both active and reactive power increase with the increase in the capacitance value, up to 100µF. Exceeding this value, both the real and reactive power start decreasing. This implies that better compensation is obtained at a capacitor value of 200µF.

(D) TCSC Compensated System

The SIMULINK model of TCSC is shown below.

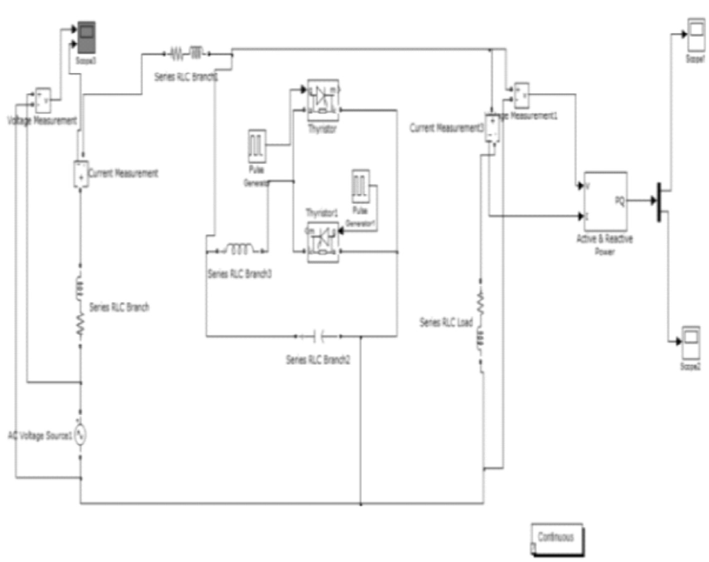

Figure 14: TCSC Compensated System

Results obtained after simulation is shown below.

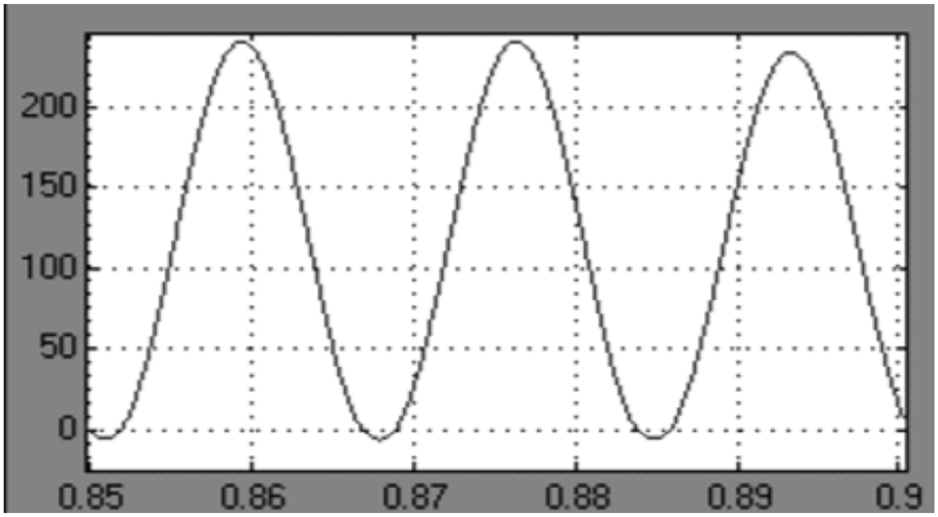

Figure 15 Real Power Flow

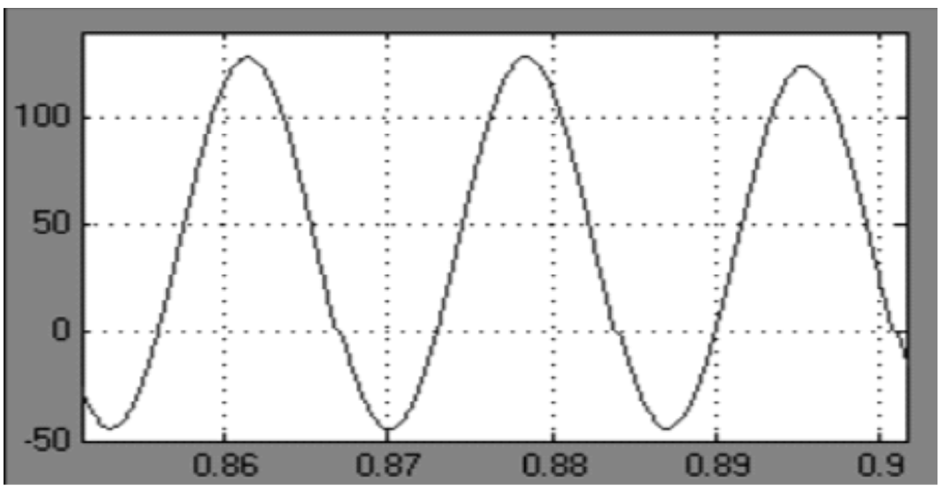

Figure 16 Reactive Power Flow

Table 3
Variation of Power Flow with Change in Capacitance

S.no	*Capacitance*	*Real Power*	*Reactive Power*
1	20	241	127.6
2	30	241.8	129.3
3	40	241	127.7
4	50	240.2	127.3
5	100	238.7	125
6	200	230	119
7	300	220	107

From the table shown above, it is seen that both active and reactive power increase with the increase in capacitance value, up to 30μF. Exceeding this value, both real and reactive power start decreasing. This implies that better compensation is obtained at a capacitor value of 30μF.

(E) UPFC Compensated System

The SIMULINK model of UPFC is shown below.

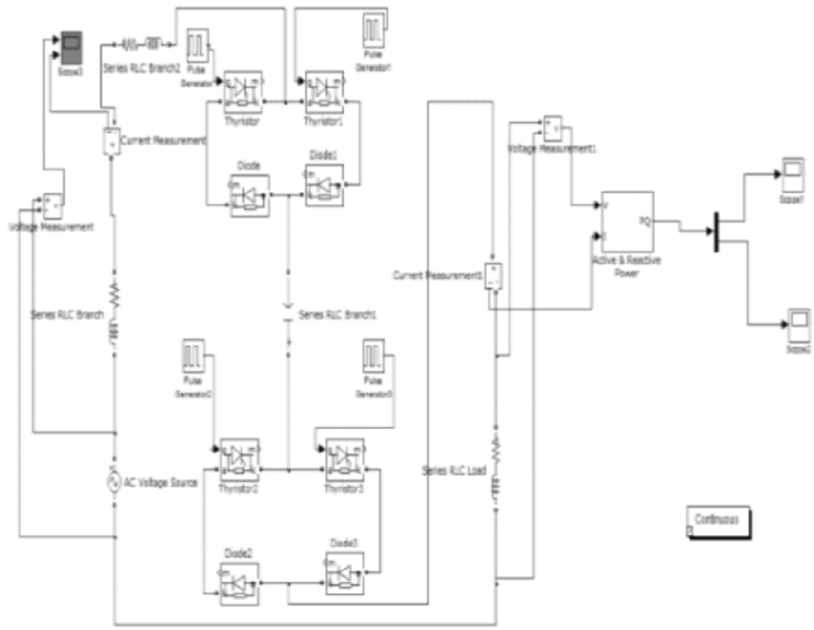

Figure 17: UPFC Compensated System

Results obtained after simulation is shown below.

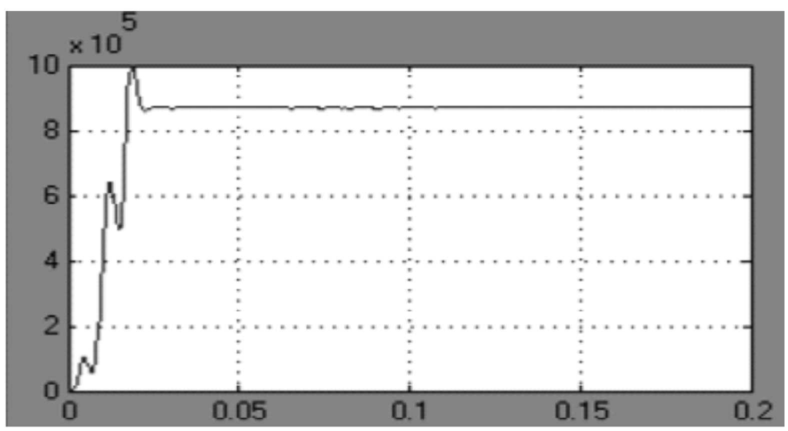

Figure 18: Real Power Flow

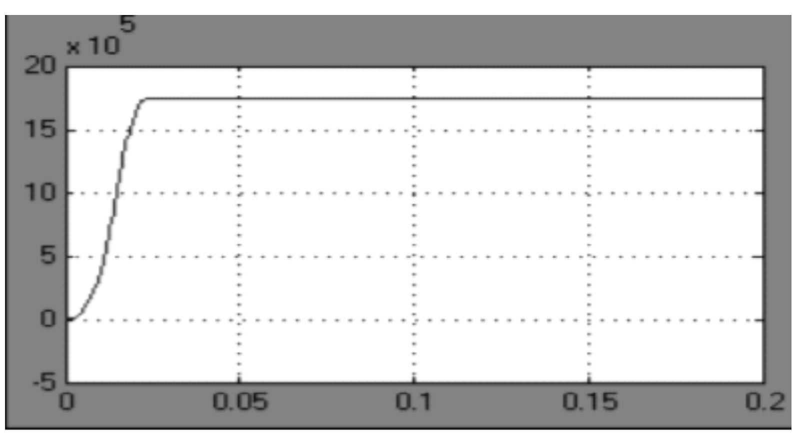

Figure 19: Reactive Power Flow

Table 4
Variation of Power Flow with Change in Capacitance

S.no	*Capacitance*	*Real Power*	*Reactive Power*
1	50	0.025	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
7	450	1.14	2.3

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

VII. COMPARISON OF POWER FLOW AMONG FACTS DEVICES

The above graph shows the behaviour of all the FACTS devices (i.e. FC-TCR, STATCOM and UPFC) for different capacitor values.

VIII. CONCLUSION

MATLAB/SIMULINK environment has been used for this comparative study using an11kv simple transmission line. This paper presentsthe performance analysis of FC-TCR, STATCOM, TCSC and UPFC FACTS devices in graphical form. Real and Reactive power flow profile have been shown to improve with all the compensating devices. Results show that in the case of FC-TCR compensation, reactive power flow improves proportionally with the increasing capacitance and is maximum at maximum value of capacitance, which is 1000µF. In the case of STATCOM compensation, a capacitor rating100µF yields the best result. For TCSC compensation, a fixed inductance of 100mH and capacitance value of 30µF gives the best result. For UPFC compensation, reactive power improves proportionally with the increasing capacitance and is maximum at maximum value of capacitance, which is 450µF. In our various schemes, FCTCR type SVC provides compensation for a capacitor value as low as 50 µF and it further improves at a higher value of capacitance without disturbing the stability. UPFC also provides better compensation in comparison to other FACTS devices.

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