SIMULATION OF REAL AND REACTIVE POWER FLOW ASSESSMENT WITH FACTS CONNECTED TO A SINGLE TRANSMISSION LINE

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Abstract— Flexible alternating current transmission systems(FACTS) technologies opens up new opportunities for controlling power and enhancing the usable capacity of present as well as new upgraded lines. FACTS devices use power electronics components to improve system performance. This paper will discuss and demonstrate, how fixed capacitor thruster controlled reactor (FC-TCR) and static synchronous compensator (STATCOM), Unified power flow controller (UPFC) are applied to control transmission system dynamic performance for system disturbance and effectively regulate system voltage. SVC and Static synchronous compensator (STATCOM) is basically a shunt connected Static VAR generator whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific power variable; typically the control variable is the SVC bus voltage. One of the major reasons for installing SVC is to improve dynamic voltage control and thus increase system load ability. Unified power flow controller (UPFC) which is used in transmission line and distribution system to improve power transfer capability and to enhance power system stability this paper shows the performance of the system for SVC, STATCOM and UPFC devices in improving the power flow in transmission line. All the simulations are carried out by using MATLAB/SIMULINK software. The simulation result shows the performance of FACTS devices in transmission line.

Keywords: FACTS, FC-TCR, STATCOM, UPFC, real and reactive power

I. INTRODUCTION

Instead of building new transmission line an effective use of existing line to their thermal limit is possible. Power generation and transmission is the complex process requiring the working of many components of power system to maximize the output. One of the main components to form a major part is reactive power in a system. To improve the performance of power system we need to manage reactive power in the system. The problems of reactive power compensation are load compensation and voltage compensation. Flexible AC Transmission Systems (FACTS) which are power electronics based devices can change parameters like impedance, voltage and phase angle [1].

Therefore they have ability to control power flow pattern and enhance the usable capacity of existing line. They can vary the parameters rapidly and continuously [2].

FACTS devices are good to improve power system efficiency, improve power factor and reduce harmonics.

FACTS controller include static synchronous compensator (STATCOM), Static VAR compensator (SVC),Thyristor controlled series capacitors(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. When the system is unable to meet the reactive power demand, voltage instability occur in the power system when the system is faulted, heavily loaded and voltage fluctuation is there. Reactive power balance can be done by using FACTS devices in transmission line which can inject or absorb reactive power in the system as per requirement [3].

II.GENERATION AND TYPES OF FACTS DEVICES

The first generation of FACTS devices was mechanically controlled capacitors and inductors. The second generation of FACTS devices replaced mechanically switches by thyristor valve control. This generation gave an improvement in speed. The third generation of FACTS devices gives the concept of VSI (voltage source converter) based devices .These devices provide multidimensional control of power system parameters [1].

A. TYPES OF FACTS CONTROLLER

Four types of Facts controller

1) Series Controllers

Series controller would be variable impedance such as capacitor, reactor etc or power electronics based variable source of main frequency, sub synchronous frequency and harmonics frequency.

They inject voltage in series with the line as long as voltage is in phase quadrature with line current. The series controller only supplies or consumes reactive variable power .Any other phase relationship involves handling of real power as well.

E.g. Static synchronous series compensator (SSSC)

2) Shunt Controller

Shunt controller is also variable impedance, variable source or combination of these .All shunt controllers inject current into the system at the point of connection as long as injected current is in phase quadrature with line voltage. Shunt controller only supplies or consumes variable reactive power. Any other phase relationship involves handling of real power as well. E.g. STATCOM (Static synchronous compensator)

3) Combined series-series controller

It could be unified controller in which series controller provided independent series reactive compensation for each

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line but also transfer real power among lines via power link.
E.g. IPFC (inter line power flow controller)

4) Combined series-shunt controller

This could be the combination of separate series shunt controller which are controlled in a coordinated manner .E.g. UPFC (unified power flow controller)[1]

III. STATIC VAR COMPENSATOR (SVC)

A. Introduction

In EHV transmission system, when voltage at bus falls below the reference value, capacitive var are to be injected. When the bus voltage become higher than reference value, inductive vars are supplied to lower the bus voltage .In conventional methods of shunt compensation ,shunt reactors are connected during low loads, and shunt capacitors are connected during heavy loads or low lagging power factor loads. Such switching operations are very slow because of greater time required for the operation of circuit breakers. Moreover circuit breakers are not suitable for frequent switching during voltage variation. These limitations have been overcome by using static var systems (SVS).In a static var system, thyristros are used as switching devices instead of circuit breakers .thyristor switching is faster than mechanical switching and also it is possible to have transient free operation by controlling the instant of switching[1].

Static var compensators (SVC) are shunt connected and shunt capacitor combination with high current, high voltage thyristor control for obtaining fast and accurate control of reactive power flow.

B. Types of Static Var Systems:
1) Thyristor controlled reactor(TCR)
2) Thyristor Switched capacitor (TSC)
3) Fixed capacitor (FC), thyristor controlled reactor (TCR) scheme.
4) Thyristor switched capacitor (TSC), Thyristor controlled reactor (TCR) scheme.

In this paper we concentrate on fixed capacitor thyristor controlled reactor (FC-TCR) scheme only.

C. Configuration of Fixed capacitor thyristor controlled reactor (FC-TCR) scheme [1]

Fixed Capacitor-Thyristor Controlled Reactor (FC-TCR) Configuration as shown in Fig 1.This arrangement provides discrete leading vars from the capacitors and continuously lagging vars from the thyristor switched reactors. Leading vars are supplied by two or more capacitors banks. The current through the reactor can be varied by controlling the firing angles of back to back pairs of thyristors connected in series with the reactor. Harmonics are generated because of switching operations. These operations are injected into the system[5].
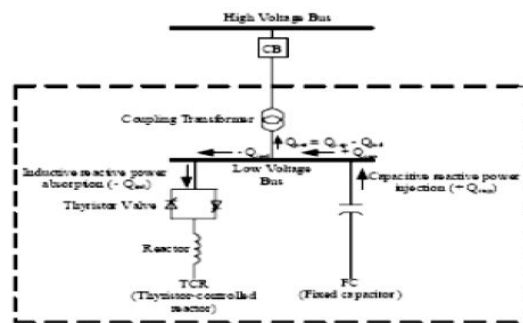

Fig.1: Fixed capacitor thyristor controlled reactor (FC-TCR)

D. Modelling of SVC

The SVC provides an excellent source of rapidly controllable reactive shunt compensation for dynamic voltage control through its utilization of high-speed thyristor switching/controlled reactive devices. An SVC is typically made up of the following major components:
1. Coupling transformer
2. Thyristor valves
3. Reactors
4. Capacitors (often tuned for harmonic filtering)

In general, the two thyristor valve controlled/switched concepts used with SVCs are the thyristor-controlled reactor (TCR) and the thyristor-switched capacitor (TSC). The TSC provides a "stepped" response and the TCR provides a "smooth" or continuously variable suseptance. Fig. 1 illustrates a TCR/FC including the operating process concept. The control objective of SVC is to maintain the desired voltage at a high voltage bus. In steady- state, the SVC will provide some steady- state control of the voltage to maintain it the highest voltage bus at the pre-defined level. If the voltage bus begins fall below its set point range, the SVC will inject reactive power (Q net) into the system (within its control limits), thereby increasing the bus voltage back to its desired voltage level. If bus voltage increases, the SVC will inject less (or TCR will absorb more) reactive power (within its control limits), and the result will be to achieve the desired bus voltage[v]

E. Advantages of SVC [2]
1) The power transfer capability of the lines is increased.
2) Transient stability of the system is improved
3) The dynamic system stability is also improved due to increased damping provided.
4) Steady state and temporary overvoltage can be controlled.
5) Load power factor is improved consequently, line losses are reduced and system efficiency is improved.
6) The dynamic response of SVC is very fast.
7) Their maintenance is easy.

F. Applications of SVC [2]
1) Static var systems provide fast, smooth and steeples variation of compensation of reactive power injected into the line. Thus it ensures an accurate voltage control of buses over a wide range of loads.

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2) The static var systems are used to control the reactive power demand of large fluctuating loads such as rolling mills, arc furnace etc.
3) In HVDC converter stations, the provision of the static var systems mainly helps to have fast control of reactive power flow. Thus voltage fluctuations are controlled and the problem of instability is overcome.

IV. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

One of the many devices under the FACTS family, a STATCOM is a regulating device which can be used to regulate the flow of reactive power in the system independent of other system parameters. STATCOM has no long term energy support on the dc side and it cannot exchange real power with the ac system.

STATCOM is a shunt connected reactive power compensation device. It is capable of generating & absorbing the reactive power. It can be improve the power system in the areas are
• Dynamic voltage control in transmission and distribution.
• Power oscillation damping in transmission system
• Transient stability.
• Voltage flicker control
• Control not only reactive power but also active power in the connected lines. [4]

A. Principle of operation

The power circuit diagram for STATCOM as shown in Figure 2. It is a controlled reactive power Source. It provides the reactive power generation and absorption by means of electronic process of the voltage and current waveforms in a voltage source. [6]
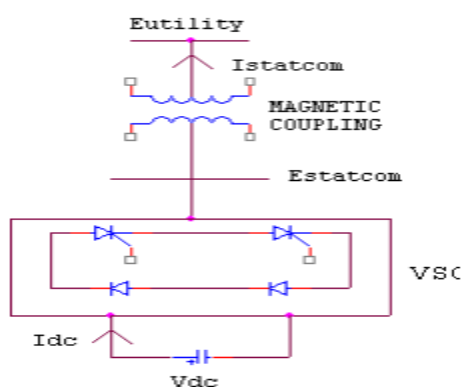

Fig.2: Power circuit diagram of Static Synchronous Compensator

A single line diagram of STATCOM is shown in Figure 3, where VSC is connected to the utility bus through the magnetic coupling transformer It is a compact design, small foot print, low noise and low magnetic impact.
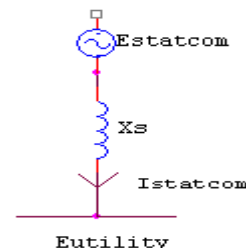

Fig.3: Single line diagram of Static Synchronous Compensator

The exchange of reactive power between the converter and AC system can be Controlled by varying the three phase output voltage, E s of the converter .

If the amplitude of the output voltage is increased above that the utility bus voltage, then the current flows through the reactance from the converter to the ac system and the converter act as a Capacitance and generates reactive power for the AC system. If the amplitude of the output voltage is decreased below the utility bus voltage, then the current flows through the reactance from the ac

System to the converter and the converter act as inductance and it absorbs the reactive power for the ac system.

If the output voltage equals the AC system, then the reactive power exchange becomes zero. In that condition, STATCOM is said to be in a floating state. STATCOM controller provides voltage support by generating or absorbing reactive power at the point of common coupling without the need of large external reactors or capacitor banks. [6]

V. UNIFIED POWER FLOW CONTROLLER (UPFC)

UPFC is a multifunctional FACTS device, which has multi usage compensation capabilty.UPFC is based on back to back voltage source converter arrangement in which one converter is in series and the other is in shunt with 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 real power can freely flow in either direction between the ac terminals of the two converters. Each converter can independently generate and absorb reactive power at its own ac output terminals[1].
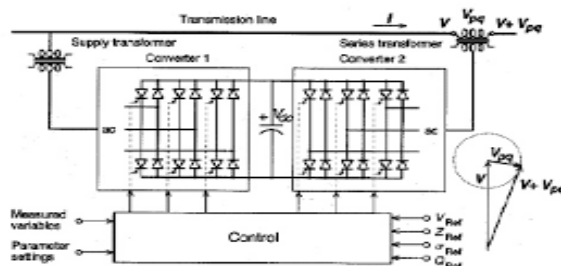

FIG.4: UNIFIED POWER FLOW CONTROLLER

Fig 4 shows the schematic diagram of UPFC.The function of convertor 1 is to supply or absorb real power

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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 transmission line via shunt connected transformer. Converter 1 can also generate or absorb controllable reactive power to provide independent shunt reactive compensation of the line. The converter 1 perform the main function of UPFC by injecting voltage in line with the help of series transformer whose phase angle can vary between 0 to 2π with respect to terminal voltage whose magnitude can be varied from 0 to defined maximum value[3].

VI.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 [4].

VII. DESCRPTION 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 hence capacitance of the line is neglected. The resistance of the line is 5Ω and the inductance is 0.06mH. The source impedance is (0.01+j0.001) Ω and the load is kept constant at 25KWand 50KVAR. 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 [4].

VIII. SIMULATION RESULTS

A. Uncompensated Model

The SIMULINK model of uncompensated system is shown below

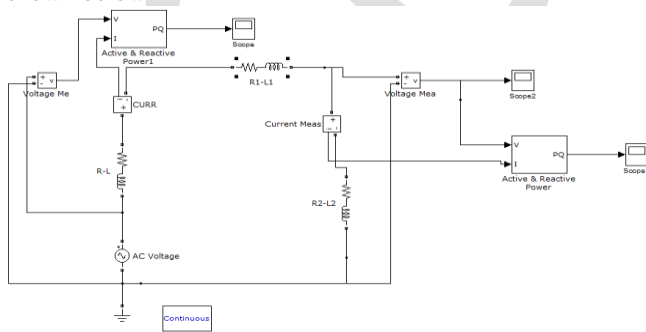
Fig 5. Uncompensated System

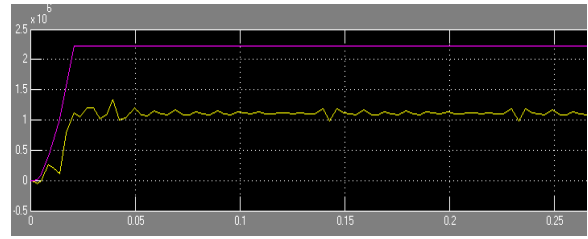The results obtained after simulation is shown below.

Fig 6 Real and reactive power flow from receiving end

B.FC-TCR compensated System

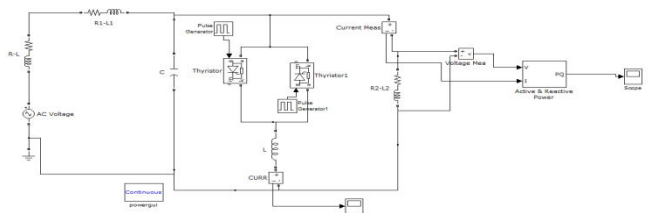The SIMULINK model of FC-TCR is shown below

Fig.7. FC-TCR Compensated System

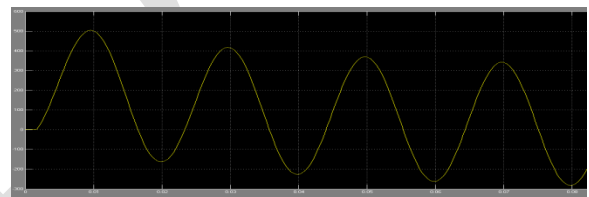The results obtained after simulation is shown below

Fig 8. TCR Reactor Current

Table1: Variation of power flow with change in capacitance

Sr. No.	L(mH)	C(µF)	P (MW)	Q (MVAR)
1	100	50	1.01	2.1
2	100	100	1.1	2.25
3	100	150	1.15	2.35
4	100	200	1.2	2.4
5	100	300	1.25	2.45
6	100	400	1.12	2.38
7	100	500	1.05	2.25
8	100	600	1	2.05
9	100	800	0.8	1.6
10	100	1000	0.6	1.2

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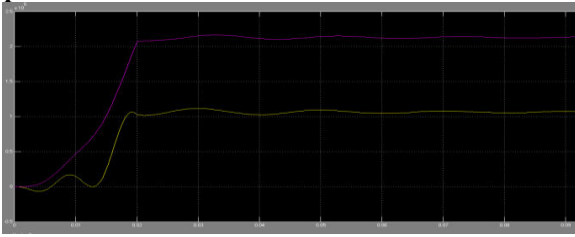
Fig 9. Real and reactive power with C=50μF and L=100mH
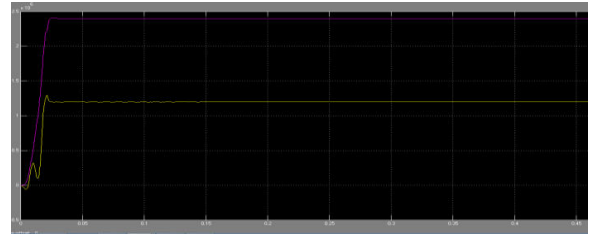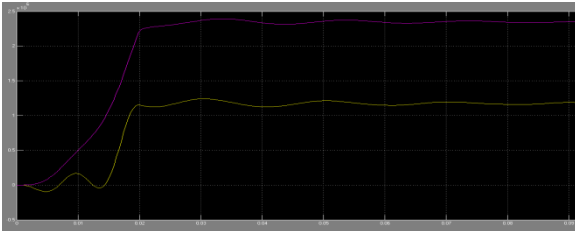

Fig 10.Real and reactive power with C=200μF and L=100mH

From table 1 and simulation results it is seen that power flow through transmission line increases with increase in capacitance up to certain value after that if you increase value of capacitance both real and reactive power starts decreasing. So better compensation is obtained at a capacitor value of 200μF.

C.STATCOM Compensated System
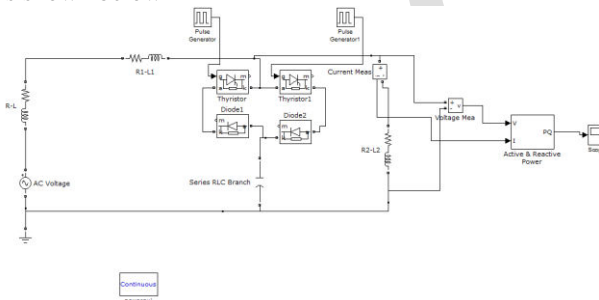The SIMULINK model of STATCOM compensated system is shown below

Fig.11. STATCOM Compensated System
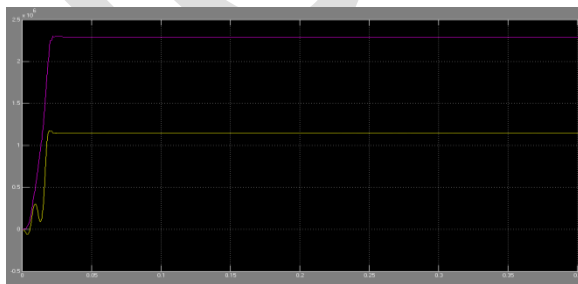Results obtained after simulation is shown below

Fig 12.Real and reactive power with C=50μF

Fig 13.Real and reactive power with C=200μF

Table 2: Variation of power flow with change in Capacitance

Sr.No.	C(μF)	P (MW)	Q (MVAR)
1	20	1.1	2.25
2	50	1.15	2.35
3	100	1.18	2.4
4	200	1.2	2.45
5	300	1.16	2.43
6	400	1.10	2.2
7	500	1.1	2

From table 2 and simulation results we can conclude that both active and reactive power increases with increase in capacitance value up to 100μF .Beyond this value both real and reactive power starts decreasing .so better compensation is obtained at a capacitor value of 200μF.

D.UPFC Compensated System

Fig.14. UPFC Compensated System
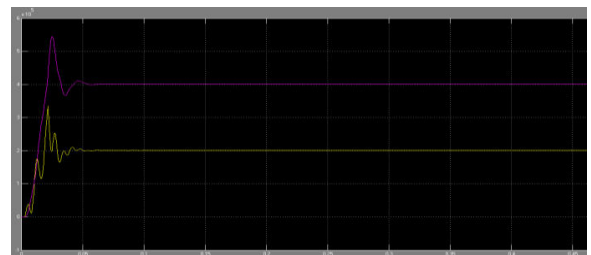
Fig15 .Real and reactive power with C=20μF

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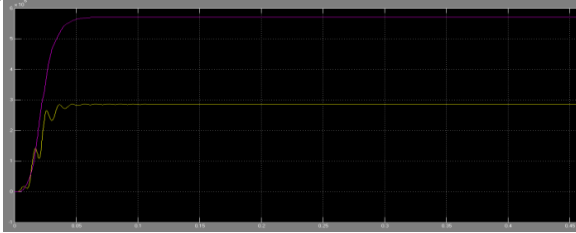
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Fig 16.Real and reactive power with C=200µF

Table 3: Variation of power flow with change in Capacitance

Sr.No.	C(µF)	P (MW)	Q (MVAR)
1	50	0.2	0.4
2	100	1.15	2.4
3	200	2.9	5.8
4	250	2.8	5.25
5	350	2.1	4.2
6	400	2	4
7	450	1.9	3.7

IX.CONCLUSION:

MATLAB/SIMULINK environment is used for this comparative study using 11KV simple transmission line. Real and reactive power flow profile are seen to improve with FC-TCR and STATCOM compensating devices .Results shows that in case of FC-TCR Compensation, reactive power flow improves proportionally with increasing capacitance up to certain value i.e. 200 µF after that if we increase the value of capacitance reactive power starts decreasing. In case of STATCOM compensation a capacitor rating 100µF yield best results. For UPFC compensation reactive power improves proportionally with increasing capacitance and is maximum at maximum value of capacitance 250 µF . Hence it is concluded that SVC and STATCOM will successfully control the dynamic performance of power system and will effectively regulate the system oscillatory disturbance and voltage regulation of the power system. UPFC also provides the better compensation in comparison to other FACTS devices. The proposed controller shows better performance and also regulates the active and reactive power along with voltage stability.

REFERENCES
[1]. Hingorani.N.G "Understanding FACTS Concepts and Technology of Flexible AC Transmission System" IEEE Press, New York(2000)
[2]. Chopade P., Bikdash M., Kateeb I, Kelkar A. D. "Reactive power management and voltage contol of large transmission system using SVC(Static VAR compensator)",IEEE conference publication(2011)
[3]. Gyugyi.L "Unified Power –flow control for flexible AC transmission system"IEE Proceedings-C,Vol 139,No 4,JULY 1992
[4]. Dipti Mohanty, Aziz Ahamad, M. A. Khan "Modelling, simulation and performance analysis of FACTS controller in transmission line" International Journal of Emerging Technology and Advanced Engineering, Volume 3,Issue 5,May 2013
[5]. Ch.Praing ,T. Tran-Quoc, R. Feuillet , J.C.Sabonnadiere ,J.Nicolas "Impact of FACTS devices on voltage and transient stability of a power system including long transmission lines " ĪEEE 0-7803-6420-1/00,2000
[6]. Alisha Banga and S. S. Kaushik "Modeling and Simulation of SVC Controller for Enhancement of Power System Stability" International Journal of Emerging Technology and Advanced Engineering July 2011
[7]. S. D. Sundarsingh, Jebaseelan and R. Raja Prabu " Reactive power control using facts devices" Indian Streams Research Journal Vol -3 , ISSUE –2, March.2013