International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

A Review and Comparison of Facts Controller

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Abstract: **---In this study paper a comprehensive review on unified power flow controller, which is a FACTS controller, is proposed. The main features of UPFC device and mathematical & simulation model was discussed. The opportunities arise through the ability of this controller to control the interrelated parameters including series impedance, shunt impedance, current, and voltage, phase angle with the damping of oscillations at various frequencies below the rated frequency are addressed. The main operation issues that have been considered are: voltage control, assets optimization, line overloads with grid congestion, voltage stability problems, angle stability problems, contingencies and economic issues.**

Keywords: **FACTS, UPFC, STATCOM, SVC, simulink etc.**

I. INTRODUCTION

Instability in power system could be relieved or at least minimized with the help of most recent developed devices called Flexible AC Transmission System (FACTS) controllers[5],[6]. The utilize Flexible AC Transmission System (FACTS) controllers in power transmission system have led to many applications of these controllers not only to improve the stability of the existing power network resources but also provide operating flexibility to the power system[7][14]. In addition, as well as relatively low investment compared to new transmission or generation facilities, that FACTS technology allows the industries to better utilize the existing transmission and generation reserves, period enhancing the power system performance. The clearly enhance power system performance, improve quality of supply with provide an optimal utilization of the existing resources [11]. The power generated would have to be transmitted to different load centres in the country through the national grid [13]. FACTS devices are a family of high-speed electronic devices, which significantly increase the power system performance by delivering or absorbing real and/or reactive power.

There are two generations for realization of power electronics-based FACTS controllers: the first generation employs conventional thyristor-switched capacitors and reactors, quadrature tap-changing transformers, that second generation employs gate turn-off (GTO) thyristor-switched converters as voltage source converters (VSCs).

The first generation has resulted in the Static Var Compensator (SVC), the Thyristor- Controlled Series Capacitor (TCSC), and the Thyristor-Controlled Phase Shifter (TCPS). The second generation has produced the Static Synchronous Compensator (STATCOM), the Static Synchronous Series Compensator (SSSC), the Unified Power Flow Controller (UPFC) [1], [2] and the Interline Power Flow Controller (IPFC).the system, large dynamic swings between different parts of the system and bottlenecks [5].

II. OVERVIEW

The two groups of FACTS controllers have distinctly different operating and performance characteristics [15]. They can be connected to power system at any appropriate location, series and shunt or combination of series and Shunt .The SVC and STATCOM are shunt connection, where as TCSC and SSSC are series connection.

Power quality problems occur at transmission line:

- The High Reactive Power Consumption at the Heavy Loads.
- Occurrence of Contingencies.
- Reverse Operation of ON Load Tap-Changer (OLTC).
- Voltage sources are far from load centers.
- Poor coordination between The multiples of FACTS controllers
- It Presences of Constant Power Load.
- Under the Heavy Loads The Transmission of Reactive power is difference

UPFC is connected in a combination of shunt and series. Number of research papers present development status of this technology from the early years up to date. So far, only one book thoroughly covers component and system wise aspects of the FACTS technology.

The deregulation (restructuring) of power networks will probably imply new loading conditions and new power flow situations. Also, some concerns are raised as to show FACTS capabilities in open access environment. This is certainly an additional challenge to be faced by the FACTS [16].

III. UNIFIED POWER FLOW CONTROLLER [UPFC]

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 systems. It offer potential advantages for the static and dynamic operation of transmission lines [3]. The UPFC was devised for the real-time control and dynamic compensation of ac transmission systems and providing the multifunctional flexibility required to solve many problems facing in the power industry. In this framework of traditional power transmission concepts, the UPFC is to control and simultaneously or selectively, all the parameters of affecting power flow in the transmission line. Its independently control both the real power flow and reactive power flow in the line, unlike all other controller [1].

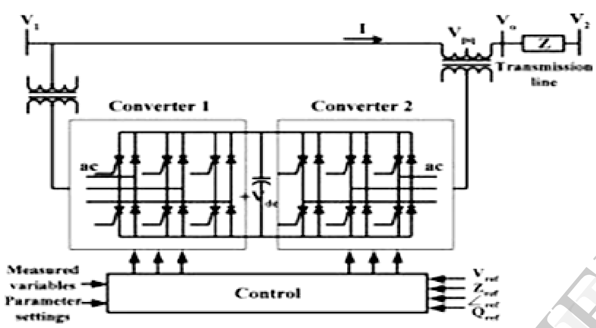

Fig. 1. UPFC Model

The Fig .1. shows the model of UPFC.It consists of two voltage source converters.

1) Series converter
2) Shunt converter

The series and shunt converter are connected with a common dc link

(a) Voltage Source Converters Used In UPFC:

STATCOM:

A static synchronous generator operated as a shunt –connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage. For the voltage-sourced converter, its ac output voltage is controlled such that it is just right for the required reactive current flow for any ac bus voltage dc capacitor voltage is automatically adjusted as require serving as a voltage source for the converter [4]. STATCOM also designed to act as an active filter to absorb system harmonics. Figures 2 and 3 shows the schematic diagram of STATCOM without energy storage system and with energy storage system

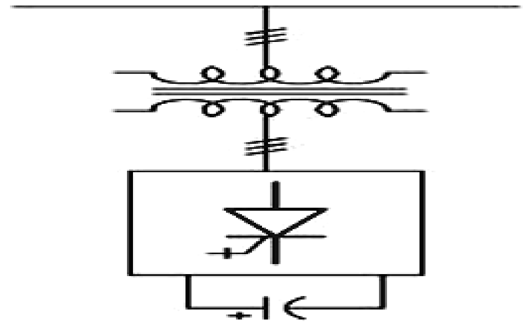

Fig. 2. shunt connected controller (STATCOM)

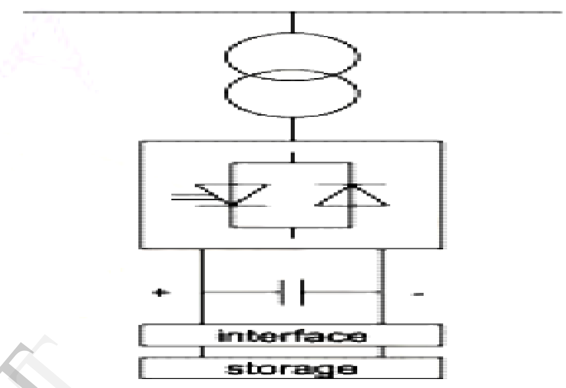

Fig. 3. STATCOM with storage i.e. battery energy storage system (BESS)

SSSC:

A Static synchronous series generator operated without an external electric energy source as a series compensator whose output voltage is in quadrature with and controlled independently of the line current for the purpose of increasing or decreasing overall reactive voltage drop across the line and thereby controlling the transmitted electric power. The SSSC include that transiently rated energy storage or energy absorbing devices to enhance the dynamic behavior of the power system by additional temporary real power compensation to increase or decrease momentarily the overall real voltage drop across the line. The SSSC shows below Fig 4.

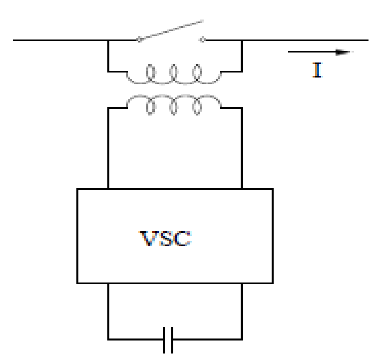

Fig. 4. Schematic of SSSC

(b) *Basic principle of UPFC:*

As in the Figure 5 show, UPFC consist of two back to back converters named VSC1 and VSC2, are operated from a DC link provided by a dc storage capacitor. These arrangements operate as an ideal ac to ac converter in which the real power can freely flow either in direction between the ac terminals of the two converts and each converter can independently generate or absorb reactive power as its own ac output terminal.

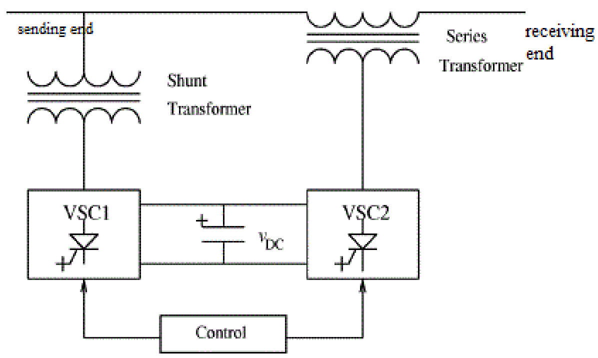

Fig. 5. basic UPFC scheme

One VSC is connected to in shunt to the transmission line via a shunt transformer and other one is connected in series through a series transformer. The DC terminal of two VSCs is coupled and this creates a path for active power exchange between the converters. VSC provide the main function of UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line via an injection transformer. This injected voltage act as a synchronous ac voltage source. That the transmission line current flows through this voltage source resulting in reactive and active power exchange between it and the ac system. The reactive power exchanged at the dc terminal. The real power exchanged at the ac terminal is converted into dc power which appears at the dc link as a real power demand [2]. And VSC1 is to supply or absorb the real power demanded by converter2 at the common dc link to support real power exchange resulting from the series voltage injection.

This dc link power demand of VSC2 is converted back to ac by VSC1 and coupled to the transmission line bus via shunt connected transformer. In addition, VSC1 can also generate or absorb controllable reactive power if it is required and thereby provide independent shunt reactive compensation for the line. Thus VSC1 can be operated at a unity power factor or to be controlled to have a reactive power exchange with the line independent of the reactive power exchanged by VSC1. Obviously, there can be no reactive power flow through the UPFC dc link.

(c) *Equivalent circuit of UPFC:*

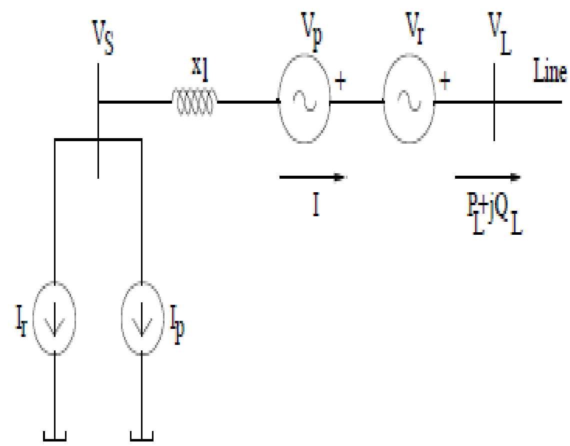

Fig. 6. equivalent circuit of UPFC

The equivalent circuit of the UPFC is shown in Fig.6 the shunt converter draws both active (Ip) and reactive current (Ir). The active current (Ip) is not independent and is related to Vp by the relation in steady state.

V Ip = IVp

The equivalent circuit of the UPFC can be viewed as a two port network. The shunt converter is connected at one port while the Series converter is connected in series with the line at the other port. The voltage at the latter port is denoted by. If the series injected voltages, Vp and Vr are controlled to regulate the power and reactive power in the line; these quantities are conveniently measured at the line side port of the UPFC.

(d) Comparison of Facts Controller

Voltage Control: SVC, UPFC, STATCOM, TCSC and TCPST/PST [10].

• Assets Optimization: SVC, UPFC, STATCOM, TCSC, TCPST/PST and SSSC

• Line Overload Limiting: UPFC, TCSC and TCPST/PST.

• Avoid congestion and re-dispatch: UPFC, TCSC and SVC.

• Voltage stability and collapse: STATCOM, UPFC, TCSC and SVC.

• Angle stability: UPFC, TCSC, SVC and SSSC.

• N-1 Contingency criteria fulfillment: UPFC, TCSC, SVC and STATCOM.

• Transmission cost minimization: UPFC, TCSC, SVC, TCPST/PST, SSSC and STATCOM.

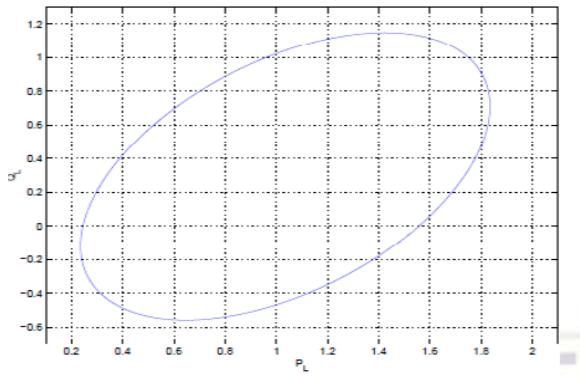

Fig. 7. operating region in the PL-QL

The above Fig .7. is an equation for ellipse with the center (Po, Qo+v²/X_L).

It is to be noted that Ir can be controlled to regulate the voltage Vsif it is not regulated by the generator connected at the sending end. Thus three variables Vs,P_L, and Q_L can be regulated by controlling Ir; $V_C$and β . It is assumed that there are no constraints imposed by the equipment ratings that will limit the control objectives.

(e) Control of UPFC

As the UPFC consists of two converters that are coupled on the DC side, the control of each converter is explained below [3]:

Control of the Shunt Converter

Shunt converter block diagram is shown in Fig. 8.The shunt converter draws a controlled current from the system. One component of this current is Ip which is automatically determined by the requirement to balance the real power supplied to the series converter through the DC link. This power balance is enforced by regulating the DC capacitor voltage by feedback control.

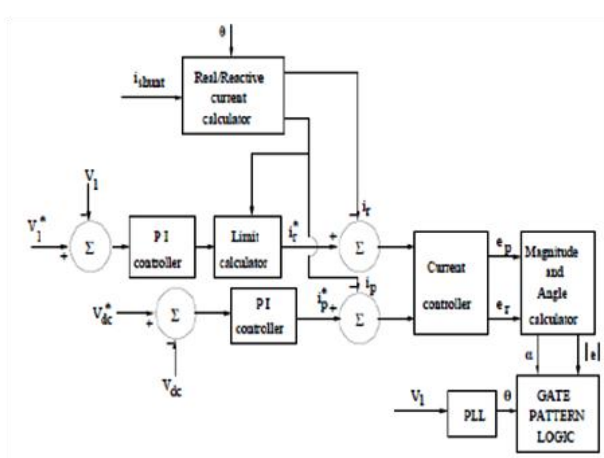

Fig. 8. Block diagram of shunt controller

The other component of the shunt converter current is the reactive current, Ir which can be controlled in a similar fashion as in a STATCOM. There are two operating (control) modes for a STATCOM or the shunt converter [17]. These are,

1. VAR control mode where the reactive current reference is determined by the inductive or capacitive VAR command. The feedback signals are obtained from current transformers (CT) typically located on the bushings of the coupling (step down) transformer.
2. Automatic voltage control mode where the reactive current reference is determined by the output of the feedback voltage controller which incorporates a droop characteristic (as in the case of a SVC or a STATCOM). The voltage feedback signals are obtained from potential transformers (PT) measuring the voltage V1 at the substation feeding the coupling transformer.

Control of the series converter

Series converter block diagram is shown in Fig.9. In this control mode, the series injected voltage is determined by a vector control system to ensure the flow of the desired current (phasor) which is maintained even during system disturbances (unless the system control dictates the modulation of the power and reactive power).

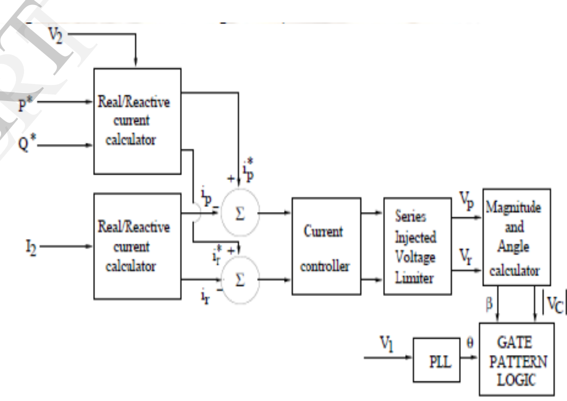

Fig. 9 .Block diagram of series controller

Although the normal conditions dictate the regulation of the complex power flow in the line, the contingency conditions require the controller to contribute to system stability by damping power oscillations [8],[9].

The different control modes for the series voltage are given:

1. In this Direct voltage injection mode the converter simply generates a voltage phasor in response to the reference input. A special case is when the desired voltage is a reactive voltage in quadrature with the line current.
2. In this Phase Angle Shifter Emulation mode the injected voltage is phase shifted relative to the

voltage by an angle is specified by the reference input[12].

3. Line impedance emulation mode where the series injected voltage is controlled in proportion to the line current.
4. Automatic power flow control mode where the reference inputs determine the required real power (P) and the reactive power (Q) at a specified location in the line[12].

(f)P-Q Controllable Region

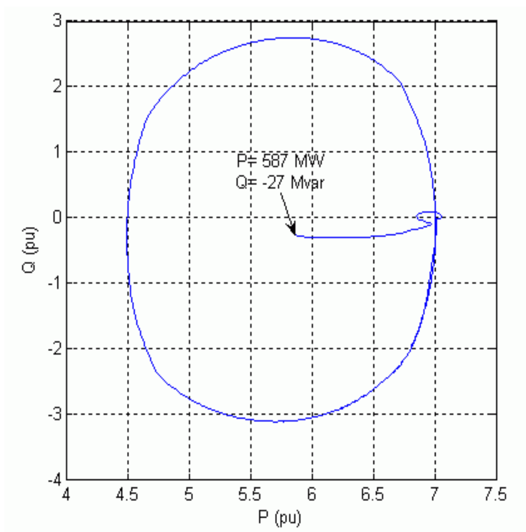

Fig. 10. P-Q Controllable Region

The above Fig.10. shows the controllable region between P-Q. In this control mode the voltage generated by the series inverter is controlled by two external signals Vd and Vq. The external signals are multiplexed at the Vdqref as input and its generated in the Vdqref magenta block.

(e) Simulink model of UPFC

There is simulink model of UPFC shows in Fig.11. which are described in MATLAB.

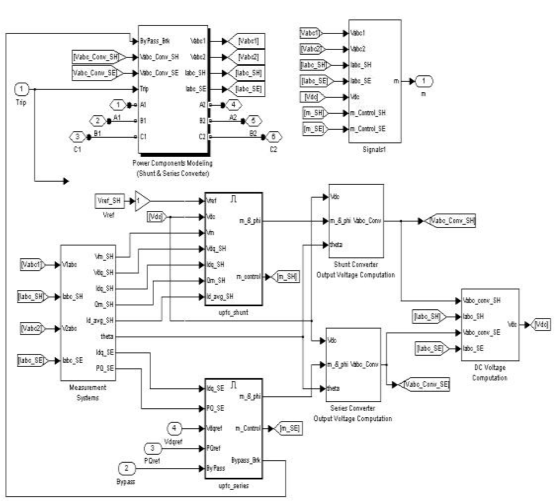

Fig. 11. UPFC (phasor model)

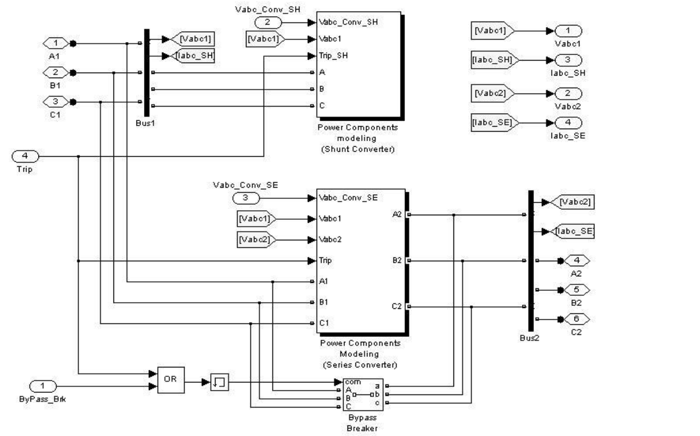

Fig. 12. shunt and series converter model

The above Fig 12 shows simulink model of Shunt and Series controller

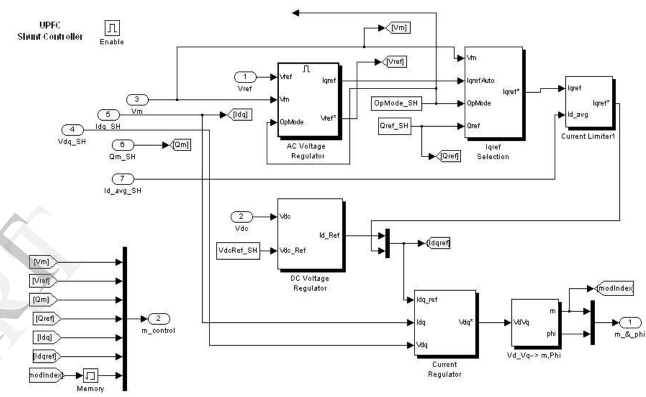

Fig. 13. series controller (SSSC)

The above Fig.13. shows simulink model of Series Controller

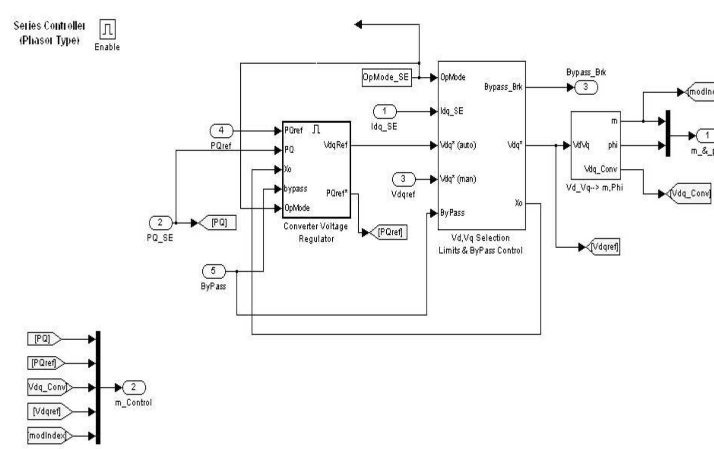

Fig.14. shunt controller (STATCOM)

The above Fig 14 shows simulink model of Shunt controller.

ISSN: 2278-0181
Vol. 2 Issue 12, December - 2013

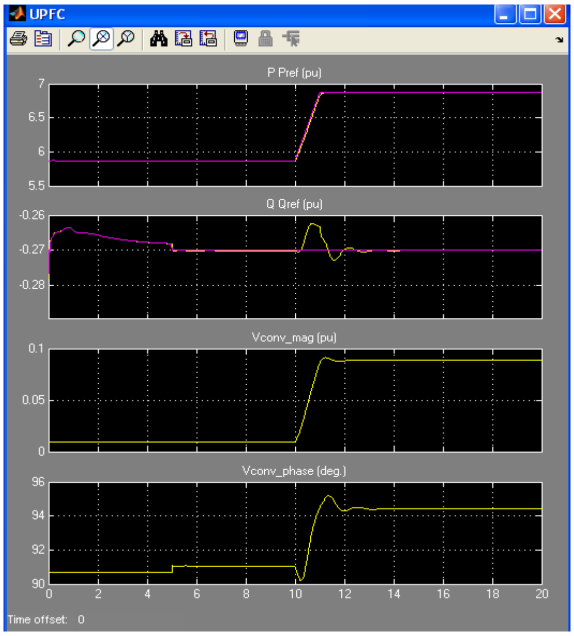

Fig. 15. Power Control

The above waveform Fig 15 is to Verify the Power data parameters of the series converter is rated in 100 MVA with a maximum voltage injection of 0.1 pu. Also the shunt converter is rated 100 MVA. And also to verify the control parameters that the shunt converter is in Voltage regulation mode. The series converter is in Power flow control mode. The UPFC reference of active power and reactive powers are set in magenta blocks labeled Pref (pu) and Qref (pu). Initially the Bypass breaker is closed and the resulting natural power flow at bus B3 is 587 MW and -27 Mvar. The Prefblock is programmed with an initial active power of 5.87pu corresponding is to the natural power flow. Then, at Time(t=10s), Pref is increased by 1 pu (100MW), from 5.87 pu to 6.87 pu, while Qref is kept constant at -0.27 pu.

IV. CONCULSION

In this study, a brief review of UPFC (FACTS), the essential features of UPFC controller and mathematical & simulation model was discussed. The potential to enhancement of power system stability was explained. In power system transmission, it is required to maintain the voltage magnitude, phase angle and line impedance. Consequently, to control power flow over designated transmission line and enhancement of power system stability FACTS devices are used in modern power system network. In this paper the role of UPFC device in power system and current status of electric power system network are addressed. Therefore, following results are found power flow control is achieved by using FACTS (UPFC) devices. Transient stability is improved and faster steady state is achieved. Hence congestion is less by improving transient stability.

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