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Application of UPFC used IEEE Bus Standard System for Minimizing the Transmission Losses

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Abstract: A modern power system is becoming more complex power flows from generating centre to load centre. Bus voltage flow from of active power & reactive power in transmission line for different loading conditions. Flexible ac transmission system (FACT) controller includes unified power flow controller (UPFC) , Static synchronous compensator (STATCOM). It should be consider real power and reactive power compensation. It able to controlling voltage, phase angle. It enhances the power transfer capability. When no UPFC installed in transmission line then real and reactive power cannot be controlled. Performance of UPFC is investigated to minimize the power loss in the transmission line. Improving the system's reactive power handling capacity via FACTS device is ready for preventing of voltage instability and hence voltage collapse. It has been performed on IEEE 14bus system to minimize the transmission losses and improve the Voltage profile. This project shows the result in Mat lab Sim link when UPFC implement in transmission system. It compare with STATCOM results.

Keywords: UPFC, STATCOM, Power electronics device, IEEE 14 bus data sheet, MATLAB/SIMULINK.

I. INTRODUCTION

Electrical power plays an important role in the present industrial society. With the increase in power demand, operation and planning of large interconnected power system are becoming more complex, so power system will become less secure and stable. Improved utilization of the existing power system is provided through the application of advanced control technologies. Power electronics based equipment, or Flexible AC Transmission Systems (FACTS), provide proven technical solutions to address these new operating challenges being presented today. FACTS are defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability. FACTS technologies allow for improved transmission system operation with minimal infrastructure investment, environmental impact, and implementation time Compared to the construction of new transmission lines. Its first concept was introduced by N.G Hingorani, in 1988[1].Since then different kinds of FACTS devices have been proposed.

The power flow through transmission line is a function of line impedance, magnitude and phase angle of bus voltage. If these parameters can be controlled, the power flow through the transmission line can be controlled in a predetermined manner .Many devices contribute to reactive power compensation and voltage profile. A transmission line, due to its physical characteristics, supplies reactive power under light loading and consumes it under heavy loading conditions. Power system voltages are controlled through the supply and consumption of reactive power. In general terms, decreasing reactive power margin causes voltage fall, while increasing reactive power margin causes voltage rise.A voltage collapse occurs when the system is trying to serve much more load than the voltage can support.

The unified power-flow controller (UPFC) is a member of the FACTS family with very attractive features. This device can independently control many parameter, so it is the combination of the properties of a static synchronous compensator (STATCOM) and static synchronous series compensator (SSSC) [2] It can be control all the three system variables namely line reactance, magnitude and phase angle difference of voltage across the line.

In this paper UPFC is treated to operate in closed loop form and control parameters of UPFC are derived to meet the required power flow along the line. The objective of the project is to achieve significant improvements in operating parameters of power systems such as, voltage profile, control of real and reactive power, and reduction in transmission line losses by adding UPFC in IEEE 14 bus system. Variable resistance and reactance model of UPFC & STATCOM is adapted into the UPFC module & STATCOM module built respectively in Matlab/Simulink software.

Finally the simulation & compare the both module results have been presented to indicate the improvement in the performance of the UPFC to control voltage, active and reactive power in transmission system. The proposed model is used to demonstrate some of the features of UPFC for optimal power flow control (OPF) applications. This paper shows that a UPFC has the capability of regulating the power flow and minimizing the losses at the same time [6].

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II. OVERVIEW OF FACTS CONTROLLER

FACTS are powerful devices to improve the voltage profile and power system enhancement.IEEE definition of FACTS Page Layout and FACTS controllers are given as [1]. Flexible AC Transmission System (FACTS):Alternating current transmission systems incorporating power electronics based and other static controllers to enhance controllability and increase power transfer capability. FACTS Controller FACTS controllers can be used for various applications to enhance power system performance. One of the greatest advantages of using FACTS controllers is that it can be used in all the three states of the power system, namely[8]:

(i) Steady state,
(ii) Transient
(iii) Post transient steady state.

TABLE I Types of FACTS controller

Sr No	First Generation Of Facts Controller	Second Generation Of Facts Controller
1	Staic Var Compensator (SVC),	Static Synchronous Compensator (STATCOM)
2	Thyristor Controlled Series Capacitor (TCSC),	Static Synchronous Series Compensator (SSSC)
3	Thyristor Controlled Phase Shifting Transformer (TCPST)	Unified Power Flow Controller (UPFC)
4		Interline Power Flow Controller (IPFC)

In this paper our focus on only UPFC & STATCOM. We will show comparison of UPFC & STATCOM with IEEE 14 bus data system.

III. THEORIES OF UPFC & STATCOM

A. Operating Principle of UPFC

The UPFC is the most versatile FACTS controller developed so far, with all encompassing capabilities of voltage regulation, series compensation, and phase shifting. It can independently and very rapidly control both real- and reactive power flows in a transmission line [5]. It is configured as shown in Fig.2 and comprises two VSCs coupled through common dc terminal. One VSC—converter1—is connected in shunt with the line through a coupling transformer; the other VSC—converter 2—is inserted in series with the transmission line through an interface transformer. The dc voltage for both converters is provided bya common capacitor bank. The series converter is controlled to inject a voltage phasor, Vpq, in series with the line, which can be varied from 0 to Vpq max.

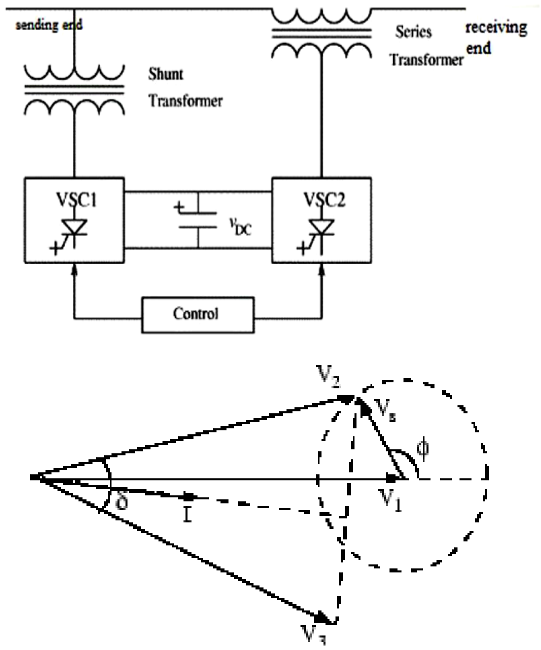

Figure 1: Basic structure of UPFC with its phasor diagram

Moreover, the phase angle of Vpq can be independently varied from 00 to 3600. In this process, the series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated/ absorbed by the series converter, the real-power generation/ absorption is made feasible by the dc-energy–storage device—that is, the capacitor. The shunt-connected converter 1 is used mainly to supply the real-power demand of converter 2, which it derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus. Thus the net real power drawn from the ac system is equal to the losses of the two converters and their coupling transformers. In addition, the shunt converter functions like a STATCOM and independently regulate the terminal voltage of the interconnected bus by generating/ absorbing a requisite amount of reactive power [6].

B. Power Flow Control Through The UPFC

The Implementation of UPFC models in power flow is essentially a controlled power flow problem. The real, reactive power, and voltage balance of the unified power-flow control (UPFC) system is analyzed. Two important results related to UPFC control are shown in this paper. First, the active and reactive power changes when UPFC implement in transmission line and without UPFC implement in transmission line. shunt converter provides all of the required reactive power during the power-flow changes Second, the UPFC bus voltage can be controlled both from the sending side and from the receiving side. Used the IEEE 14 bus data and thyristor in UPFC and STATCOM model. The basic control strategy is such that the shunt converter controls the transmission-line reactive power flow and the dc-link voltage. The series converter controls the transmission line real power flow and the UPFC bus voltage. The real/reactive power coordination controllers in the UPFC control system can obtain good performance both during transient and stable conditions

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that means power losses are minimize [9]. The real and reactive power equations are :

$$P=V_1V_2/X \ * \sin(\delta_1-\delta_2)$$

$$Q= V_2/X * (V_1-V_2)$$

C. Basic Operating Principal Of STATCOM
The STATCOM is based on a solid state synchronous voltage source which generates a balanced set of three sinusoidal voltages at the fundamental frequency with rapidly controllable amplitude and phase angle. Configuration of a STATCOM is shown in Fig.2. Basically it consists of a voltage source converter (V_{SC}), a coupling transformer and a dc capacitor. Control of reactive current and hence the susceptance presented to power system is possible by variation of the magnitude of output voltage (V_{vsc}) with respect to bus voltage (V_b) and thus operating the STATCOM in inductive region or capacitive region.[14]

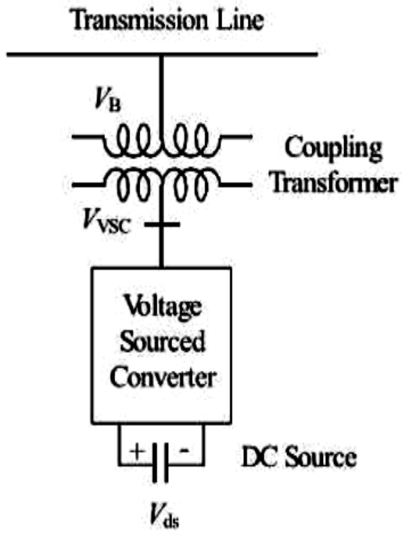

Figure 2: STATCOM connected to transmission line

TABLE II Comparison between FACTS devices for power system stability Enhancement

FACTS Devices	Power system stability enhancement	Load flow	Voltage control	Transient stability	Dynamic stability
UPFC	YES	High	High	Medium	Medium
TCSC	YES	Medium	Low	High	Medium
SVC	YES	Low	High	Low	Medium
SSSC	YES	low	High	medium	Medium

IV. BENEFITS OF UPFC IN TRANSMISSION SYSTEM

A. Environmental Benefit of UPFC
In past, researchers have used various techniques in power flow studies to incorporate UPFC to minimize losses, generation costs and maximize load ability, social welfare.

The construction of new transmission line has negative impact on the environment. FACTS devices help to distribute the electrical energy more economically through better utilization of existing installation there by reducing the need for additional transmission lines. To set the optimal location of the UPFC and it's parameter setting by using Simulink technique. That's why it can be minimise the power loss [9]

B. Cost of UPFC
The cost of FACTS devices are huge but FACTS devices can save the system from potential threat of system collapse, which can have very serious consequences on other economic sector as well. It can help to avoid the wide spread blackout. The opportunity cost of FACTS controllers in these situations has to taken into consideration [10]

In the normal operation state of power system, the production costs of active power can be minimized by economic power dispatch, and delivery costs due to transmission system loss can be also minimized by active power control of UPFC, incorporated with minimization of production cost.the FACTS maintenance cost is very minimum. In addition, as the number of transmission line increases, the probability of fault occurring in a line is also high. So, by utilizing the transmission systems optimally with the use of FACTS, the total number of line fault is minimized, thus reducing the maintenance costs.

C. Minimum Power Loss
The capabilities of UPFC are the power loss reduction in the power system. It presented an injection model of UPFC to investigate its effect on power flow and loss reduction in power system. The best place for UPFC for loss reduction is in the main transmission line. It enhances the stability of the power system.

The optimal location and the best parameter setting of Unified Power Flow Controller (UPFC) for minimizing the active and reactive power losses in the power system. Simulations have been implemented in MATLAB, by using IEEE 14-bus standard system. This paper shows the comparison of UPFC and STATCOM results.

D. Application of UPFC
The application of FACTS controllers includes transient stability improvement, dynamic stability and voltage stability enhancement. One of the most important capabilities expected of FACTS applications is to be able to reduce the impact of the primary disturbance. The impact reduction for contingencies can be achieved

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through dynamic voltage support (STATCOM), dynamic flow control (TCSC) or both with the use of UPFC [8].

E. Improved Quality of Supply System

Modern industries require high quality of electricity supply including constant voltage and frequency, and no supply interruptions. Voltage dips, frequency variations or the loss of supply can lead to interruptions in manufacturing processes with high economic losses. FACTS devices can help to provide the required quality of supply.

V. IEEE 14 BUS DATA SYSTEM

The IEEE 14-bus test case represents a simple approximation of the American Electric Power system as of February 1962 [1]. It has 14 buses, 5 generators, and 11 loads.

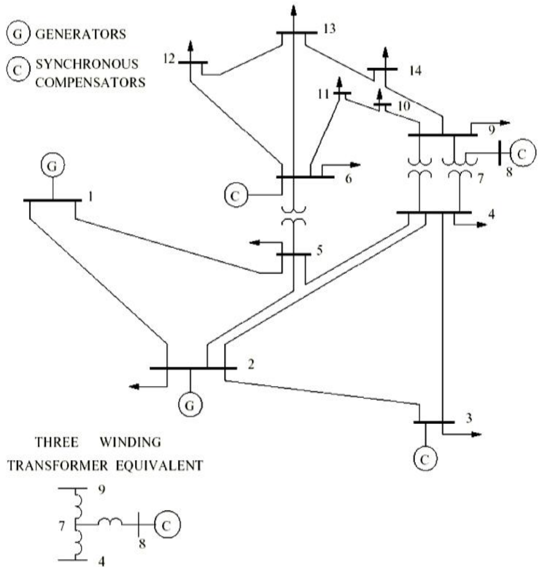

Figure 3: Structure of IEEE 14 bus system

TABLE III Line Data for IEEE 14 bus system

Line No.	From Bus	To Bus	Line Impedance (p.μ)		Half Line Charging Susceptance (p. μ)	MVA Rating
			Resistance	Reactance		
1	1	2	0.0.1938	0.05917	0.02640	120
2	1	5	0.05403	0.22304	0.02190	65
3	2	3	0.04699	0.19797	0.01870	36
4	2	4	0.05811	0.17632	0.02460	65
5	2	5	0.05695	0.17388	0.01700	50
6	3	4	0.06701	0.17103	0.01730	65
7	4	5	0.01335	0.04211	0.00640	45
8	4	7	0	0.20912	0	55
9	4	9	0	0.55618	0	32
10	5	6	0	0.25202	0	45
11	6	11	0.09498	0.1989	0	18
12	6	12	0.12291	0.25581	0	32
13	6	13	0.06615	0.13027	0	32
14	7	8	0	0.17615	0	32
15	7	9	0	0.11001	0	32
16	9	10	0.03181	0.0845	0	32
17	9	14	0.12711	0.27038	0	32
18	10	11	0.08205	0.19207	0	12
19	12	13	0.22092	0.19988	0	12
20	13	14	0.17093	0.34802	0	12

TABLE IV Transformer Tap setting data – IEEE 14 Bus system.

From bus	To bus	Tap setting value (p.u.)
4	7	0.978
4	9	0.969
5	6	0.932

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TABLE V Bus Data and Load Flow Results – IEEE Bus system

Bus no.	Bus voltage		Generation		Load	
	Magnitude (P.U.)	Phase angle (degree)	Real power (MW)	Reactive power (MVAR)	Real power (MW)	Reactive power (MVAR)
1	1.060	0.0	232.4	-16.01	0.0	0.0
2	1.045	-4.98	40.0	45.41	21.7	12.7
3	1.010	-12.74	0.0	25.28	94.2	19.0
4	1.019	-10.28	0.0	0.0	47.8	-3.9
5	1.020	-8.76	0.0	0.0	7.6	1.6
6	1.070	-14.22	0.0	13.62	11.2	7.5
7	1.062	-13.34	0.0	0.0	0.0	0.0
8	1.090	-13.34	0.0	18.24	0.0	0.0
9	1.056	-14.92	0.0	0.0	29.5	16.6
10	1.051	-15.08	0.0	0.0	9.0	5.8
11	1.057	-14.78	0.0	0.0	3.5	1.8
12	1.055	-15.07	0.0	0.0	6.1	1.6
13	1.050	-15.15	0.0	0.0	13.5	5.8
14	1.036	-16.02	0.0	0.0	14.9	5.0

VI. MATLAB SIMULATION WAVEFORMS & RESULT

A MATLAB program is used for IEEE 14 bus system with standard IEEE 14 bus system data input file. After simulating the program, it displays results, that is voltage, active & Reactive powers and line losses. MATLAB Simulink model of without UPFC, with UPFC and with STATCOM as shown in below. The Simulink Model/diagram for Standard IEEE 14-bus network with UPFC and STATCOM in MATLAB/Simulink Environment developed is shown in the Figure. The respective waveforms are given in the figure below. A comparative performance evaluation with and without UPFC in the transmission line has been studied [3].

UPFC system has been built to test power control in transmission line. IGBT technology allow for switching frequency with low loss .The UPFC device is inserted into a transmission line standard IEEE 14 bus system as shown in figure. The Simulink/ model for standard IEEE 14 bus network with UPFC in Matlab / Simulink developed. A comparative performance evaluation of UPFC & STATCOM in transmission line has been studied [2][15]. Required in this simulation. Voltage magnitude as at load buses of the system is better in case of UPFC compared to STATCOM. A real & reactive power can be improved in UPFC system as compare to STATCOM. We have to take different phase angle and active and reactive power loss are minimize. It can be shown below result table.

Figure 4 & 5 shows Real & Reactive power across load and output voltage across load without UPFC respectively Figure 6 & 7 shows Real & Reactive power across load and output voltage across load when UPFC inserted in network. Figure 8 & 9 shows the Real & Reactive power across load and output voltage across load with STATCOM. These waveforms are obtained by simulating the Simulink diagram for test system in environment of sim power toolbox of MATLAB

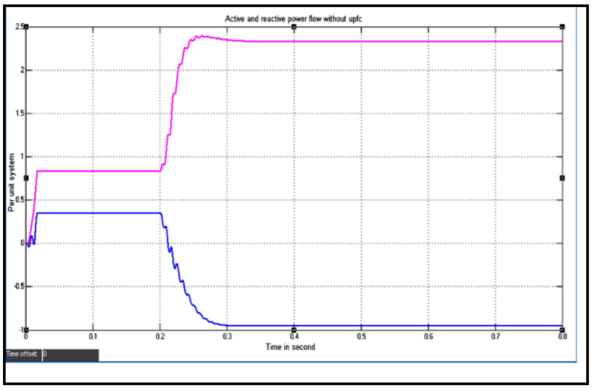
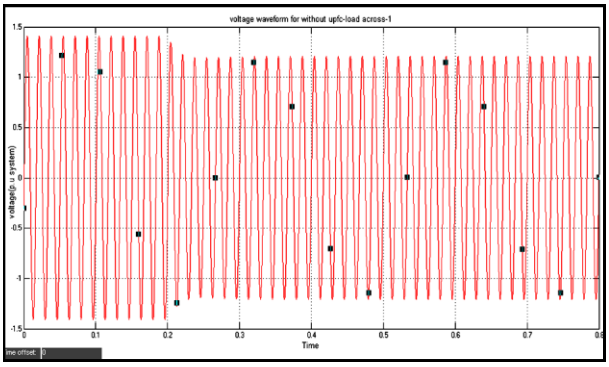


Figure4: Active and reactive power flow for without UPFC



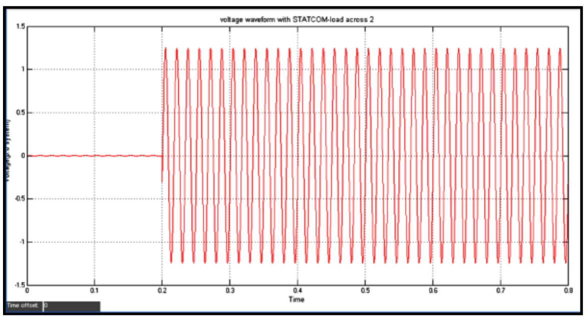


Figure 5: voltage waveform without UPFC-across load-12

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Fig.4 shows the real power and reactive power cannot be improve within highest settling time. Fig.5 shows load voltage profile cannot maintain when secondary load is inserted.

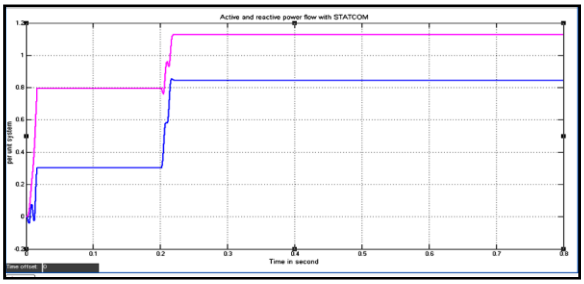


Figure 6: active and reactive power flow with STATCOM

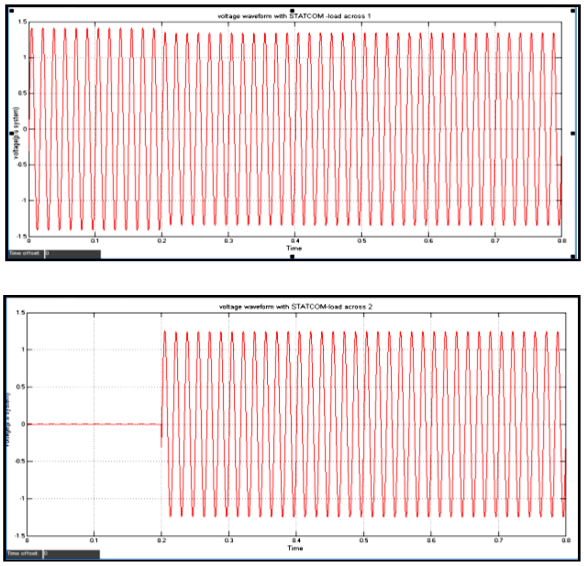


Figure 7: voltage waveform with STATCOM-across load 1-2

Fig.6 shows the real power and reactive power can be improve within high settling time than UPFC. Fig.7 shows load voltage profile is maintained.

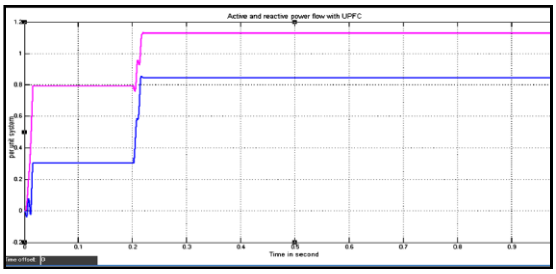
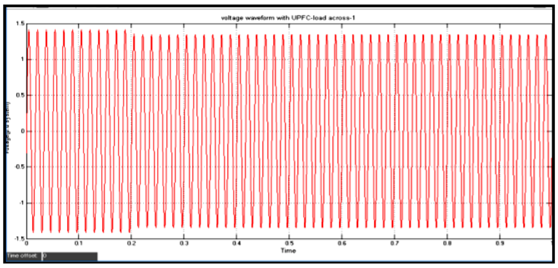


Figure8: active and reactive power flow with UPFC



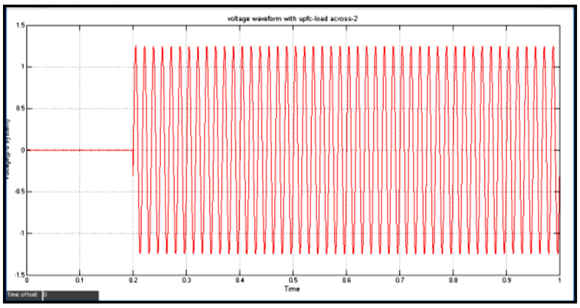


Figure 9: voltage waveform with UPFC- across load12

Fig.8 shows the real power and reactive power can be improve. Reactive power can be compensate in this controller within very less settling time as compared to STATCOM. Fig.9 shows load voltage profile is good as compared to STATCOM.

A. RESULT TABLE

TABLE VI POWER FLOW WITH & WITHOUT STATCOM & UPFC

Bus	**FACTS DEVICES**	**Net active power flow (Per unit system)**	**Net reactive power flow (Per unit system)**	**Settling time**
1-2	Without UPFC	2.327	-0.92	0.34
	With STATCOM	1.217	0.67	0.27
	With UPFC	1.13	0.84	0.24

TABLE VII Voltage profile

Without & With FACTS device	**Load voltage across 1-2**
Without any FACTS device	1.195
With STATCOM	1.332
With UPFC	1.335

FACT devices are use to improve the voltage profile in power system. In this paper we use IEEE 14 bus system as test model & connected it with STATCOM & UPFC on MATLAB Simulink. The improved of UPFC & STATCOM on the test system is examined and compare the voltage profile at load side and settling time when load is connected.

UPFC is inserted between any of two buses, to improve the power flow between the lines to a pre specified value. it has been observed that the power flow between the lines is improved to a pre-specified value. The active and reactive power is improved in UPFC controller and settling time is very less in UPFC system.

The bus voltage profile of a test system is improves with UPFC in compare to STATCOM. It also optimize the real & reactive power control over best system and minimize the transmission losses.

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