

# Improvement of Voltage Profile and Reduce Power System Losses by using Multi Type Facts Devices

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## ABSTRACT

In emerging electric power systems, increased transactions often lead to the situations where the system no longer remains in secure operating region. The flexible Ac transmission system (FACTS) controllers can play an important role in the power system security enhancement. However, due to high capital investment, it is necessary to locate these controllers optimally in the power system. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics. Placement of these devices in suitable location can lead to control in line flow and maintain bus voltages in desired level and so improve voltage stability margins.

This paper proposes a systematic method by which optimal location of MUTI TYPE FACTS DEVICES to be installed. FACTS DEVICES model is incorporated into a Newton-Raphson algorithm to perform load flow analysis. Optimizing its location becomes a concern when coming to the practical implementation stage. Proposed algorithm is tested on IEEE 5 bus power system for optimal allocation of multi-type FACTS devices and results are presented.

## Keywords

Voltage Stability, FACTS Devices, Optimal Allocation.

## 1. INTRODUCTION

Modern power systems are prone to widespread failures. With the increase in power demand, operation and planning of large interconnected power system are becoming more and more complex, so power system will become less secure. Operating environment, conventional planning and operating methods can leave power system exposed to instabilities. Voltage instability is one of the phenomena which have result in a major blackout. Moreover, with the fast development of restructuring, the problem of voltage stability has become a major concern in deregulated power systems. To maintain security of such systems, it is desirable to plan suitable measures to improve power system security and increase voltage stability margins. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics. Placement of these devices in suitable location can lead to control in line flow and maintain bus voltages in desired level and so improve voltage stability margins.

FACTS devices can regulate the active and reactive-power control as well as adaptive to voltage magnitude control simultaneously by their fast control characteristics and their continuous compensating capability and so reduce flow of heavily loaded lines and maintain voltages in desired level.[1]

Besides, FACTS devices can improve both transient and

small signal stability margins. Controlling the power flows in the network, under normal and abnormal conditions of the network, can help to reduce flows in heavily loaded lines, reduce system power loss, and so improve the stability and performance of the system without generation rescheduling or topological changes in the network [1]. Because of the considerable costs of the FACTS devices, it is so mementos to find out the optimal location for placement of these devices to improve voltage stability margins and enhance network security [2-7].

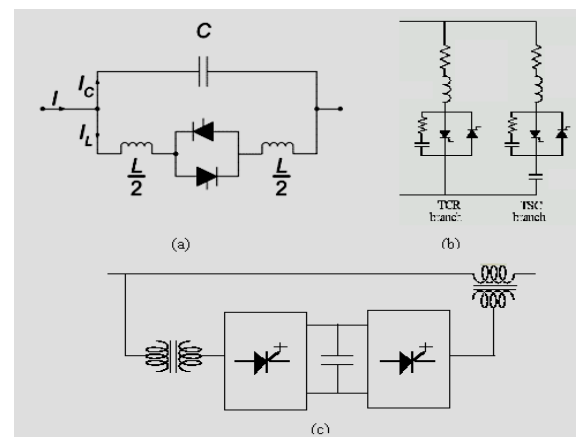


Fig 1. Considered FACTS Devices (a) TCSC (b) SVC (c) UPFC

Effect of FACTS devices on power system security, reliability and loadability has been studied according to proper control objectives [5-15]. Some of papers have been tried to find suitable location for FACTS devices to improve power system security and loadability [14-17]. Optimal allocation of these devices in deregulated power systems has been presented in [18-19].

## 2. FACTS DEVICES MODEL

### 2.1 FACTS Devices

In this paper, three different FACTS devices have been selected to place in suitable location to improve voltage stability margins in power system. These are TCSC, SVC and UPFC. These are shown in Fig 1.

TCSC can change line reactance and SVC can be used to control reactive power in network. UPFC is the most versatile member of FACTS devices family and can be applied in order to control all power flow parameters (i.e. line impedance, bus voltage, and phase angle). Power flow can be controlled and optimized by changing power system parameters using FACTS devices. So optimal choice and allocation of FACTS devices can result in suitable utilization in power system.

## 2.2 Mathematical model of FACTS Devices

In this paper steady state model of FACTS devices are developed for power flow studies. So TCSC is modeled simply to just modify the reactance of transmission line. SVC and UPFC are modeled using the power injection models [20-24]. Models integrated into transmission line for TCSC and UPFC and SVC is modeled is incorporated into the bus as shunt element of transmission line. Mathematical models for FACTS devices are implemented by MATLAB programming language.

i TCSC:- Thyristor Controlled Series Capacitor (TCSC) is a series FACTS device which allows rapid and continuous changes of the transmission line impedance. It has great application potential in accurately regulating the power flow on a transmission line, damping inter-area power oscillations, mitigating sub synchronous resonance (SSR) and improving transient stability. The characteristics of a TCSC at steady-state and very low frequencies can be studied using fundamental frequency analytical models .

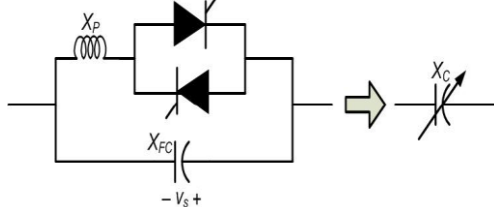


Fig 2. Model of TCSC

In this paper TCSC is modeled by changing transmission line reactance as below:

$$X_{ij} = X_{line} + X_{TCSC} \text{ -----(1)}$$

$$X_{TCSC} = r_{TCSC} \cdot X_{line} \text{ -----(2)}$$

Where  $X_{line}$  is reactance of transmission line and is compensation factor of TCSC. Rating of TCSC is depended on transmission line where it is located. To prevent overcompensation, TCSC reactance is chosen between  $-0.7 X_{line}$  to  $0.2X_{line}$  [18].

ii. SVC :- Static var systems are applied by utilities in transmission applications for several purposes. The primary purpose is usually rapid control of voltage at weak points in a network. Installations may be the midpoint of transmission interconnections or in load areas. In this paper, SVC is assumed to be located at load side.

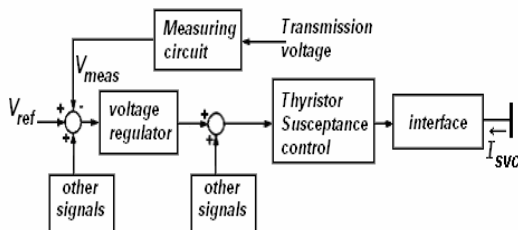


Fig 3: Basic Model of SVC

SVC can be used for both inductive and capacitive compensation. In this paper SVC is modeled as an ideal reactive power injection at bus i :

$$\Delta Q_i = Q_{SVC} \text{ -----(3)}$$

iii. UPFC:- The unified power flow controller (UPFC) is the most versatile among a variety FACTS devices which can be used for power flow control, enhancement of transient stability, damping system oscillations and voltage regulations. Load flow control with unified power flow controller can maintain the reliable system operation in the event of additionally demanded power transients. UPFC has been proved to be an effective means for regulating voltage profile and power flow in modern power systems. It facilitates greater control of power, such that it flows on the prescribed transmission routes and secure loading of transmission lines to levels nearer to their thermal limits is possible. In power systems, FACTS DEVICES are used for the best utilization of the existing transmission lines. UPFC is located in order to maximize the system load ability while observing thermal and voltage constraints. Power transmitted by the network to the consumers is increased keeping the power system in a secure state in terms of branch loading and voltage levels.

Two types of UPFC models are reported in papers [22-25]. One is coupled model [22] and other is decoupled model [23-25]. In the first type, UPFC is modeled with series combination of a voltage source and impedance in the transmission line. In decoupled model, UPFC is modeled with two separated buses. First model is more complex compared with the second one because modification of Jacobian matrix in coupled model is inevitable.

While decoupled model can be easily implemented in conventional power flow algorithms without modification of Jacobian matrix elements, in this paper, decoupled model used for modeling UPFC in power flow study (Fig 4)

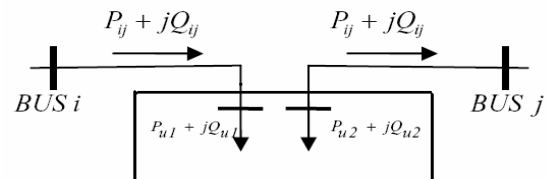


Figure 4. Decoupled model for UPFC

UPFC controls power flow of the transmission line where is installed. To obtain UPFC model in load flow study, it is represented by four variables:  $P_{u1}$ ,  $Q_{u1}$ ,  $P_{u2}$ ,  $Q_{u2}$ . Assuming UPFC to be lossless, real power flow from bus i to bus j can be expressed as:

$$P_{ij} = P_{u1} \text{ -----(4)}$$

Although UPFC can control the power flow, but cannot generate the real power. So:

$$P_{u1} + P_{u2} = 0 \text{ -----(5)}$$

Each reactive power output of UPFC  $Q_{u1}$ ,  $Q_{u2}$  can be set to an arbitrary value depend on rating of UPFC to maintain bus voltage.

## 3. SIMULATION RESULTS

### 3.1 Introduction

Simulation studies were done for different scenarios in IEEE 5 bus power system. Five different scenarios are considered:

Scenario 1: power System normal operation (without FACTS devices installation).

Scenario 2: one TCSC is installed

Scenario 3: one SVC is installed

Scenario 4: one UPFC is installed

Scenario 5: Multi-type (TCSC, SVC and UPFC)FACTS devices are installed.

The first scenario is normal operation of network without installing any device. In second, third and fourth scenario just installation of one device is considered. Multi-type FACTS devices installation is considered in 5th scenario. In this case three different kinds of FACTS devices (shunt, series and combinational compensation device) are used to place in optimal location to improve the voltage profile and reduce the losses of power system.

### 3.2 Simulation without FACTS Devices

Table 1: Power Flow Solution by Newton-Raphson Method

BUS NO	VOLTAGE MAGNITUDE	VOLTAGE ANGLE	LOAD GENERATION			
			MW	MVAR	MW PU	MVAR PU
1	1.06000	0.00000	0.00	0.00	129.5	7.421
2	1.04744	-2.80635	20.0	10.00	40.00	30.00
3	1.02418	-4.09969	45.0	15.00	0.00	0.00
4	1.02357	-5.32914	40.0	5.00	0.00	0.00
5	1.01794	-6.15026	60.0	10.00	0.00	0.00
TOT			165.0	40.00	169.5	22.57

Table 2 : Line losses without FACTS devices

BUSNO FROM:	TO	LINE LOSSES	
		MW	MVAR
1	2	1.41045	-2.43083
1	3	1.19196	-1.85547
2	3	0.35152	-3.23757
2	4	0.44134	-2.96560
2	5	1.12525	0.17577
3	4	0.03560	-1.981
4	5	0.03071	-5.11758
TOTAL		4.58683	-17.42109

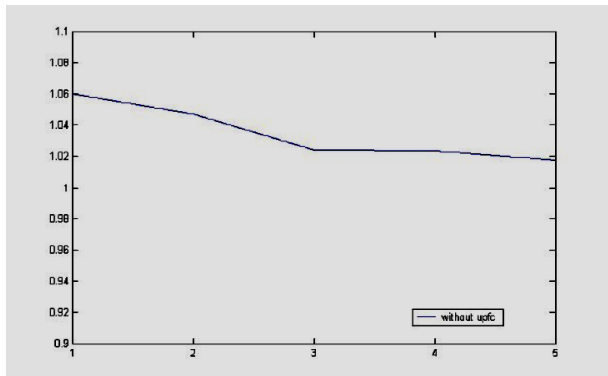


Fig 5: Voltage profile of the test system without FACTS devices.

### 3.3 Simulation with TCSC

Table 3 : Line losses with TCSC

BUS From	BUS To	REAL POWER LOSS	REACTIVE POWER LOSS
2	3	6.47328	-11.66943
2	4	6.53247	-12.03645
2	5	6.32411	-23.88476
3	2	6.47642	-11.66949
3	4	6.12821	-10.85432
4	2	6.53872	-12.03452
4	3	6.12834	-10.85342
4	5	6.15325	-10.87238
5	2	6.32984	-13.85347
5	4	6.15096	-10.87543

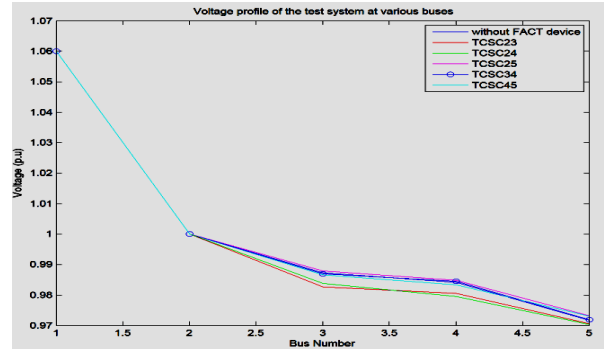


Fig 6: voltage profile of system with TCSC

Here we can observe that by placing TCSC can improve the voltage profile and losses are reduced. The best location for TCSC is between bus 2 and bus 5 to minimize the losses.

### 3.4 Simulation with SVC

Table 4 : Line losses with SVC

BUS From	BUS To	REAL POWER LOSS	REACTIVE POWER LOSS
2	3	6.6734	-9.5535
2	4	6.8625	-8.9328
2	5	11.3428	5.5864
3	2	6.7284	-9.6334
3	4	6.3158	-10.3962
4	2	6.9372	-8.9694
4	3	6.4121	-10.4043
4	5	6.1319	-11.1986
5	2	11.294	4.7654
5	4	6.1243	-11.2188

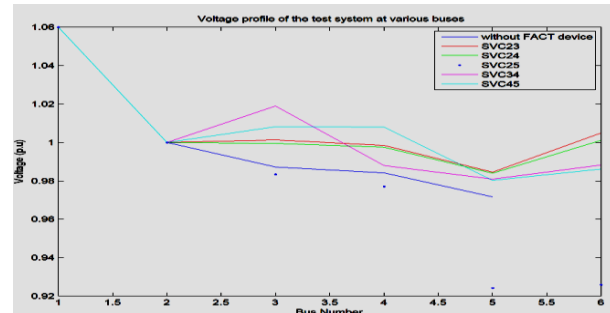


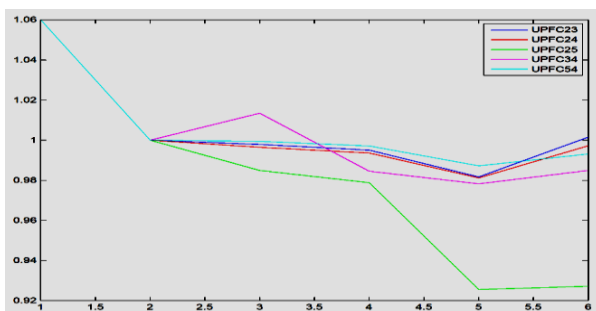
Fig 7: voltage profile of system with SVC

SVC is placed at different locations and observed that voltage profile is improved and losses are reduced. The best location for SVC is between bus 2 and bus 3 to minimize the losses.

### 3.5 Simulation with UPFC

Table 5 : Line losses with UPFC

BUS From	BUS To	REAL POWER LOSS	REACTIVE POWER LOSS
2	3	4.79012	-16.85673
2	4	4.70994	-17.10167
2	5	5.02372	-15.57745
3	2	2.92128	-23.45038
3	4	5.04984	-16.31023
4	2	2.91293	-23.44640
4	3	2.91293	-23.44640
4	5	6.22885	-12.66832
5	2	1.37279	-28.66214
5	4	1.37279	-28.66214



**Fig 8: voltage profile of the system with UPFC**

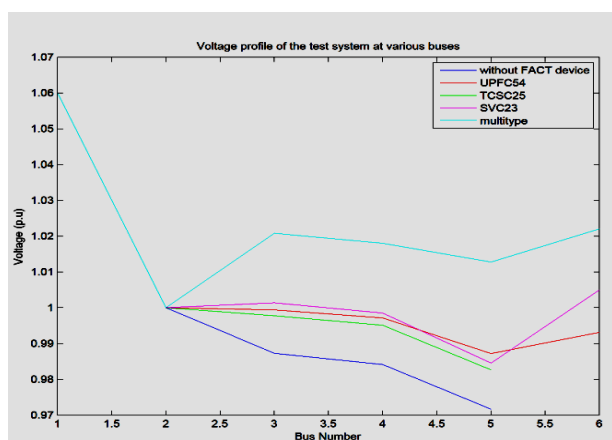
UPFC is placed at different locations and observed that voltage profile is improved and losses are reduced. The optimal location for UPFC is between bus 5 and bus 4 to minimize the losses.

### 3.6 Simulation with Multi type FACTS

Total Power Loss in the best voltage profile Scenario of each Configuration:

**Table 6 : Line losses with Multi-type FACTS Devices**

System	Total Active Power loss (MW)	Total Reactive Power loss (MVAR)
Without FACT Device	6.122	-10.773
UPFC-5--4	2.858	-20.944
TCSC-2--5	6.329	-13.884
SVC-2—3	6.673	-9.558
Multi-type FACT Devices	3.162	-20.837



**Fig 9: voltage profile of system with multi-type FACTS devices.**

So multi-type FACTS devices should be placed in optimal location to improve voltage profile and reduce losses in the network. Table 6 shows optimal location of devices in scenarios. Voltage profiles are shown for different scenarios in Fig. 9.

This indicates that the best voltage profile is achieved by multi-type installation of multi type FACTS devices. But economic aspects must be considered.

## 4. CONCLUSION

This paper gives a concise idea on each of the FACT devices, UPFC, TCSC and SVC. Their individual contribution towards the improvement of voltage profile and reduction of power losses has been tested on a 5-bus system. The combination of all the three FACTS devices has been considered, as a multi

type FACTS devices effect on the maintenance of the voltage profile and reduction of power loss. The performance of UPFC on the system, when located optimally is considered to be best comparatively with respect to each of the three devices. The multi-type FACTS devices located at their own optimal locations is observed to have a better voltage profile and power loss.

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