PERFORMANCE ANALYSIS OF STATIC VAR COMPENSATORS (SVC), ON CONGESTION MANAGEMANT AND VOLTAGE PROFILE IN POWER SYSTEMS WITH PSAT TOOLBOX

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Abstract: *Transmission congestion must be managed so that transmission capacity is utilized as efficiently as possible with minimal social welfare loss-usually by system operator. Congestion management must provide incentives for investments in transmission network and generation capacity in the right areas. Minimizing the risks associated with different congestion management methods are important task for every market participant who is trading between different areas. The idea for solving this problem is the use of FACTS devices especially the use of Static Var Compensators (SVC). In this paper the study of SVC with its various modes of operation is investigated. Finally by help of modeling of a power system in MATLAB/PSAT toolbox, and by installing SVC in transmission line, its use as power flow controller and voltage injection is seen. Conclusion is made on different results to see the benefit of SVC in power system.*

Keywords: *FACTS, Power Flow Control, MATLAB/PSAT Toolbox, Voltage Control, Congestion Managemet.*

1. Introduction

In recent years, with the deregulation of the electricity market, the traditional concepts and practices of power systems are changed. This led to the introduction of Flexible AC Transmission system (FACTS) such as thyristor Controlled Series Compensations (TCSC), Thyristor controlled phase angle Regulators (TCPR), Unified Power Flow Controllers (UPFC) and Static Var Compensator (SVC). These devices controls the power flow in the network, reduces the flow in heavily loaded lines there by resulting in an increase loadability, low system losses, improved stability of network and reduced cost of production [1] [2] [3] [4], It is important to ascertain the location of these devices because of their significant costs. S.Jerbex et al [5] provides an idea regarding the optimal locations of fact devices, without considering the investment cost of FACTS device and their impact on the generation cost. L.J.Cai et al [6] later studied about the optimal location considering the generation cost of the power plants and investment cost of the Devices.J.baskaran et al [7], discussed optimal location problem by power loss reduction.

SVC is member of FACTS family that is connected in shunt with the system. Even though the primary purpose of shunt FACTS devices are to support bus voltage by injecting (or absorbing) reactive power, they are also capable of improving the transient stability by increasing (decreasing) the power transfer capability when the machine angle increases (decreases), which is achieved by operating the shunt FACTS devices in capacitive (inductive) mode.

Previous works on the topic prove that shunt FACTS devices give maximum benefit from their stabilized voltage support when sited at the mid-point of the transmission line. The proof of maximum increase in power transfer capability is based on the simplified model of the line neglecting line resistance and capacitance. However, for long transmission lines, when the actual model

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of the line is considered, the results may deviate significantly from those found for the simplified model.

The primary objective of our project is to find the maximum power and the corresponding location of the shunt FACTS devices when the actual line model is considered. Based on the simplified line model it has been proved that the center or midpoint of a transmission line is the optimal location for shunt FACTS devices. These placements give better performance in improving transient stability in a long transmission line with predefined direction of real power flow.

There is various solution approaches for OPF available, which include interior point methods. In this paper the optimal power flow problem with SVC is solved by Newton Method.

2. Transmission Line Model

In this section, the transmission line is modeled by a two-port, four terminal networks as shown.

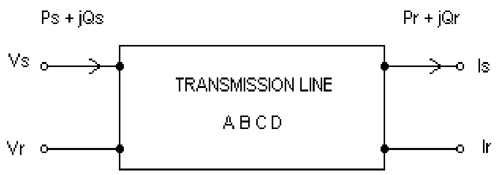

Figure 1: Two port four terminal model of a transmission line.

Transmission lines are operated with a balanced three phase load ; the analysis can therefore proceed on a per phase basis. This can be regarded as a two port network, wherein the sending end voltage Vs and current are related to the receiving end voltage Vr and current Ir through ABCD constants as:

$$V_S = AV_R + BI_R$$
$$I_S = CV_R + DI_R \quad (1)$$

The ABCD constants of a line of length l, having a series impedance of z Ω/km and shunt admittance of y S/km are given by: A = D = cosh (γl); B = Zc sinh (γl); C=sinh (γ l)

where,

$$Z_C = \sqrt{\frac{z}{y}} \qquad \gamma = \sqrt{zy}$$

Z_C = characteristic impedance of the line.
γ= propagation constant of the line.
z = series impedance/unit length/phase.
y = shunt admittance/unit length/phase to neutral.
l = transmission line length.
α= attenuation constant
β= phase constant.

2.1. Power flow through a transmission line for a actualLine model

The principle of power flow through a transmission line is illustrated through a single transmission line (2-node/2-bus system).

Let us consider receiving-end voltage as a reference phasor (| Vs | ∠ 0) and let the sending end voltage lead it by an angle δis known as the torque angle.

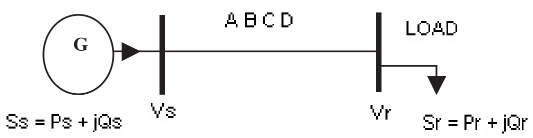

Figure 2: A Two bus system.

The complex power leaving the receiving end and entering the sending-end of the transmission line can be expressed as

$$S_r = P_r + jQ_r = V_r I_r^*$$
$$S_S = P_S + jQ_S = V_S I_S^* \quad (2)$$

Receiving and sending end currents can be expressed in terms of receiving and sending end voltages.

$$I_r = \left|\frac{1}{B}\right| |V_S| \angle(\delta - \beta) - \left|\frac{A}{B}\right| |V_r| \angle(\alpha - \beta)$$
$$I_S = \left|\frac{D}{B}\right| |V_S| \angle(\alpha + \delta - \beta) - \left|\frac{1}{B}\right| |V_r| \angle - \beta \quad (3)$$

we can write the real and reactive powers at the receiving-end and the sending end as

$$P_S = C_1 \cos(\beta - \alpha) - C_2 \cos(\beta + \delta)$$
$$P_R = C_2 \cos(\beta - \delta) - C_3 \cos(\beta - \alpha)$$
$$Q_S = C_1 \sin(\beta - \alpha) - C_2 \sin(\beta + \delta) \quad (4)$$
$$Q_R = C_2 \sin(\beta - \delta) - C_3 \sin(\beta + \delta)$$

3. Power Flow in a Transmission Line with FACTS Devices

3.1. Shunt FACTS devices in a power system

In fig. 3, the line is transferring power from a large generating station to an infinite bus and equipped with a shunt FACTS device at point m. a parameter k is used to show the fraction of line length at which the FACTS device is placed.

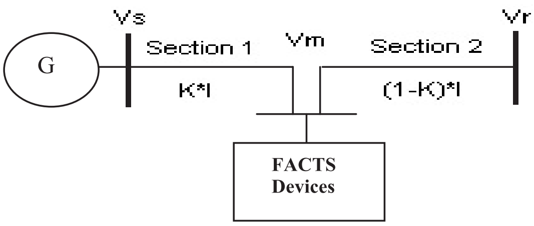

Figure 3: Transmission Line with the FACTS device.

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3.2. For a Simplified Model

The power transfer through the line for given values of Sending End and Receiving End voltage magnitude is given by eq. 5 and can be written as

$$P = \frac{V_S V_R}{X} \sin\delta \tag{5}$$

here the maximum power P_m is $\frac{V_S V_R}{X}$

when a shunt FACTS device is connected to the line both P_m and δ_m are increased and their values depend on the k factor. The power transfer through the line is then given by

$$P = \frac{V_S V_m}{k X_L} \sin\delta_S = \frac{V_R V_m}{(1-k) X_L} \tag{6}$$

here the sending end power is equal to the receiving end power because the line is lossless.

$$P = \frac{P_0 \sin\delta_S}{k} = \frac{P_0 \sin\delta_R}{1-k} \tag{7}$$

From eq. (7), the value of transmission angle for a particular value of k can be given by δ = δS + δR

$$\delta = \sin^{-1} k \frac{p}{p_0} + \sin^{-1}(1-k)\frac{p}{p_0} \tag{8}$$

3.2. For Actual Line Model

The ABCD constants of a line of length l, having a series impedance of z ohms/km and shunt admittance of y S/km with FACTS devices the active and reactive power flows at the SE and RE of the line can be shown in the table1.

Table 1: Sending End and Receiving End Real and Reactive power with the Shunt FACTS Devices

Section 1	Section 2
$P_S = C_1\cos(\beta-\alpha) - C_2\cos(\beta+\delta_S)$	$P_S = C_1\cos(\beta-\alpha) - C_2\cos(\beta+\delta_R)$
$Q_S = C_1\sin(\beta-\alpha) - C_2\sin(\beta+\delta_S)$	$Q_S = C_1\sin(\beta-\alpha) - C_2\sin(\beta+\delta_R)$
$P_R = C_2\cos(\beta-\delta_S) - C_3\cos(\beta-\alpha)$	$P_R = C_2\cos(\beta-\delta_S) - C_3\cos(\beta-\alpha)$
$Q_R = C_2\sin(\beta-\delta_S) - C_3\sin(\beta+\delta)$	$Q_R = C_2\sin(\beta-\delta_R) - C_3\sin(\beta+\delta)$

4. Mathematical Model of SVC Power

The power-injected model is a good model for FACTS devices because it will handle them well in load flow computation problem. Since, this method will not destroy the existing impedance matrix Z; it would be easy while implementing in load flow programs. In fact, the injected power model is convenient and enough for power system with FACTS devices.

The power flows of the line connected between bus-i and bus-j having series impedance z and without any FACTS controllers [11] [12], can be written as,

$$z = r_{ij} + jx_{ij}\left(= \frac{1}{(g_{ij} + jb_{ij})}\right) \tag{9}$$

$$P_{ij} = V_i^2 g_{ij} - V_i V_j \left(g_{ij} \cos\delta_{ij} + b_{ij} \sin\delta_{ij} \right) \quad (10)$$

$$Q_{ij} = -V_i^2 \left(b_{ij} + B_{sh} \right) - V_i V_j \left(g_{ij} \sin\delta_{ij} - b_{ij} \cos\delta_{ij} \right) \quad (11)$$

where V_i, V_j, δ_{ij} are the voltage magnitudes at bus-i and bus-j and voltage angle difference between bus-i and bus-j, where:

$$g_{ij} = \frac{r_{ij}}{r_{ij}^2 + x_{ij}^2}, \quad b_{ij} = \frac{-x_{ij}}{r_{ij}^2 + x_{ij}^2} \quad (12)$$

Similarly, the real power (P_{ij}) and reactive power (Q_{ij}) flows from bus-j to bus-i in the line can be written as

$$P_{ji} = V_j^2 g_{ij} - V_i V_j \left(g_{ij} \cos\delta_{ij} - b_{ij} \sin\delta_{ij} \right) \quad (13)$$

$$Q_{ji} = -V_j^2 \left(b_{ij} + B_{sh} \right) + V_i V_j \left(g_{ij} \sin\delta_{ij} + b_{ij} \cos\delta_{ij} \right) \quad (14)$$

The Mathematical model of the SVC is developed mainly to perform the Steady state research. The SVC is modeled using the power injection method [5].

4.1. Static Representation of SVC

The primary purpose of SVC is usually control of voltages at weak points in a network. This may be installed at midpoint of the transmission line.

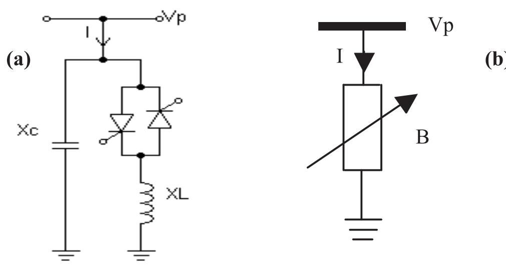

Figure 4: SVC configuration: (a) SVC firing angle model, (b) SVC total susceptance model

The SVC load flow models can be developed treating SVC susceptance as control variable. Assuming that SVC is connected at node-p to maintain the bus voltage at Vp.

The reactive power injected by the controller is given by output of an SVC can be expressed as follows [12]:

$$Q_{PSVC} = -V_P^2 B_{PSVC} \quad (15)$$

The linearized load flow models make use of eq. (16) to modify the corresponding Jacobian elements at SVC bus. The SVC load flow model can be developed treating SVC total susceptance as control variable (B_{SVC}).

or the reactive power output of an SVC can be expressed as follows:

$$Q_{SVC} = V_i \frac{(V_i - V_r)}{X_{sl}} \quad (16)$$

where, Xsl is the equivalent slope reactance in p.u.equal to the slope of voltage control characteristic, and Vr are reference voltage magnitude. The exact loss formula of a system having N number of buses is: [9] [10]

$$P_{ltc} = \sum_{j=1}^{N} \sum_{k=1}^{N} \left[\alpha_{jk} \left(P_j P_k + Q_j Q_k \right) + \beta_{jk} \left(Q_j P_k - P_j Q_k \right) \right] \quad (17)$$

where P_j, P_k and Q_j, Q_k respectively, are real and reactive power injected at bus-j and αjk, βjk are the loss coefficients defined by:

$$\alpha_{jk} = \frac{R_{jk}}{V_i V_k} \cos(\delta_j - \delta_k)$$
$$\beta_{jk} = \frac{R_{jk}}{V_i V_k} \sin(\delta_j - \delta_k) \quad (18)$$

where R_{jk} is the real part of the j-kth element of [Z_{bus}] matrix. The total loss if a SVC, one at a time, is used, can be written as follows [10].

$$P_{lk} = \left(P_{lkc} - \left[P_i(com) + P_j(com) \right] \right) \quad (19)$$

More than one device used at time, can be expressed as

$$P_{lk} = \left(P_{lkc} - \sum_{d=1}^{Nd} \left[P_i(com) + P_j(com) \right] \right) \quad (20)$$

N_d is number of device is to be located at various lines.

5. Mathematical Model of SVC Power

In this study emphasis is laid to project the use of SVC in Western System Coordinating Council (WSCC) 9-bus system shown in Fig. 5 to increase the power flow and to get better the voltage profile of the system with MATLAB/PSAT toolbox [12].

Model block of single line diagram: Using the concept of the control system a power system is taken to implement the application of SVC. The SVC total susceptance model is simulated in PSAT toolbox to see the effect of SVC on a power system. Investigation is carried out to verify the utility of FACT device.

Figure 5 illustrates application study the steady-state and dynamic performance of a SVC used to relieve power congestion and improve power flow in a transmission system.

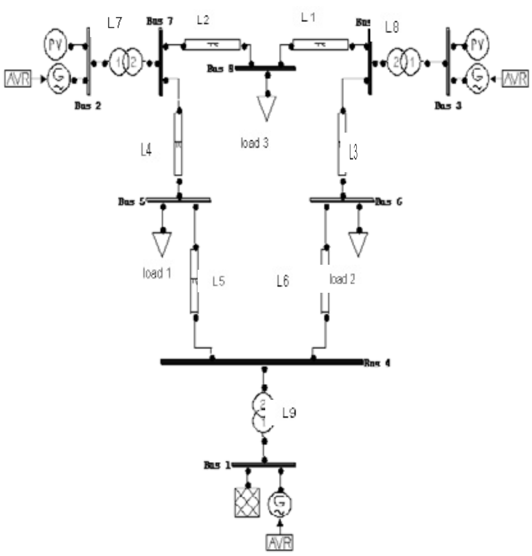

Figure 5. Test WSCC (9-bus, 3-machine) power system.

The load flow analysis and the single line diagram simulation are done on power flow simulator. This software helps to calculate the power flow, the voltage magnitude and voltage angle at each bus and the each transmission lines of the system.

A SVC is used to control the power flow and maintain voltage in a test WSCC (9-bus, 3-machine) power system. This system, connected in a loop configuration, consists essentially of nine buses (B1 to B9) interconnected through six transmission lines (L1 to L6) and three 18 kV/230 kV transformer banks with power rated equals to 100 MVA. Three Specifications of synchronous machines connected to buses 1,2,3 on the 16.5, 18, 13.8 kv buses respectively that generate a total loads of 315 MW (Fig. 5) which their data are presented in Table 3. Each plant model includes a speed regulator, an excitation system as well as a Power System Stabilizer (PSS). In normal operation, most of the 215 MW generation capacity of power plant #2 is exported to the 18 kV equivalents through transformers connected between buses.

The single line diagram illustrated in Fig. 5 is implemented on MATLAB/PSAT toolbox to check the validity of the SVC controller. This system with SVC is shown in Fig. 6. The Model of SVC is based upon the simulations at total susceptance control mode. The important keys to note in the block diagram are:

- ✓ Use of Bypass breaker: Used to connect or disconnect SVC Block from power system.
- ✓ The reference voltage Vdref: Reference for voltage injection
- ✓ Power flow analysis at load flow indicated by arrows: comparison with and without SVC.

For this illustration we consider a contingency case where only two transformers out of three are available (Tr2 = 2*100 MVA). The load flow shows that most of the power generated by plant#3 is transmitted through the 200 MVA transformer bank (140 MW out of 200 MW) and that rest of power is circulating in the loop. Transformer Tr2 is therefore overloaded by 99 MVA. This will now illustrate how a SVC can maintain voltage buses at reference and how can relieve this power congestion.

The SVC connected at the power system is used to congestion management by regulate voltage profile and control reactive powers injection.

Voltage and Reactive power flow control with the SVC: Parameters of the SVC are given in the table 8. Initially the Bypass breaker is closed and the resulting natural power flow at bus B8 is – 100 MW and – 22.127 Mvar; the voltage is increased from 1.0159 p.u to 1.0250 p.u The Vref of SVC connected at bus B8 is programmed at 1.0262 p.u with an initial reactive power injection of 0.12873 p.u corresponding to the natural power flow.

Grid characteristics: The information of test power system including Buses data, transmission lines data, and power plants data loads data and transformer and slack and PV buses are listed as Table 2-9.

Based on test power system shown in Fig. 5 the Optimal Power Flow Analysis (OPF) has been implemented. Figure 5 shows the case that in this one the SVC is not implemented. This case is considered in order to investigate the effect of in OPF [13].

Table 2. Bus data

Bus no.	Rating voltage
1	16.5
2	18.0
3	13.8
4	230
5	230
6	230
7	230
8	230
9	230

Table 3. Loads data

Load no	Power (MVA)	Voltage rate (kV)	Active Power (p.u)	Reactive Power (p.u)
1	100	230	1.25	0.50
2	100	230	0.90	0.30
3	100	230	1.00	0.35

Table 4. Transmission Line data

Line no.	Power (MVA)	Voltage (KV)	R (p.u)	X (p.u)	B/2 (p.u)
1	100	230	0.0119	0.1008	0.1045
2	100	230	0.0085	0.0720	0.0745
3	100	230	0.0390	0.1700	0.1790
4	100	230	0.0320	0.1610	0.1530
5	100	230	0.0100	0.0850	0.0880
6	100	230	0.0170	0.0920	0.0790

Table 5. Transformers data

Trans no.	Power rate (MVA)	Primary Voltage (kV)	Secondary voltage (kV)	R (p.u)	X (p.u)
line 7	100	18.0	230	0	0.0625
line 8	100	13.8	230	0	0.0586
line 9	100	16.5	230	0	0.0576

Table 6. Slack bus connected to bus 1 data

Slack bus connected to bus 1	Value
Power rate (MVA)	100
Voltage rate (kV)	16.5
Voltage magnitude (p.u)	1.04
Reference phase (rad)	0
Qmax (p.u)	99
Qmin (p.u)	-99
Vmax (p.u)	1.1
Vmin (p.u)	0.9
Active power guess (p.u)	0.8

Table 7. PV bus for load flow data

Specification of PV bus	PV Bus	
	Connected to bus 2	Connected to bus 3
Power rate (MVA)	100	100
Voltage rate (KV)	18	13.8
Active power (p.u)	1.63	0.85
Voltage magnitude (p.u)	1.025	1.025
Qmax (p.u)	99	99
Qmin (p.u)	-99	-99
Vmax (p.u)	1.1	1.1
Vmin (p.u)	0.9	0.9

Figure 6 shows the test power system with SVC in Bus 8. This location is given after very of course the other candied locations for installing SVC are not shown in this study…, because the best results of OPF are obtained by the location of SVC device in bus 8.

Table 8. Synchronous machine data

Specification Of synchronous Machine	Synchronous machine		
	Connected to bus 1	Connected to bus 2	Connected to bus 3
Power rate (MVA)	100	100	100
Voltage rate (kV)	16.5	18	13.8
Ra	0	0	0
X1	0	0	0
Xd	0.146	0.8958	1.3125
X'd	0.0608	0.1198	0.1813
X"d	0	0	0
$T'd_0$	8.96	6	5.89
$T"d_0$	0	0	0
Xq	0.0969	0.8645	1.2578
X'q	0.0969	0.1969	0.25
X"q	0	0	0
$T'q_0$	0.310	0.5350	0.6
$T"q_0$	0	0	0
M= 2H	2*23.64	12.80	6.02

Table 9. Characteristics of SVC

Power rate (MVA)	100
Voltage rate (kV)	230
Frequency	60
Reference voltage (p.u)	1.00
Capacitive reactance Xc (p.u)	0.10
Inductive reactance Xl (p.u)	0.20
Bmax (p.u)	1.00
Bmin (p.u)	-1.00

6. Results and Discussion

The results are in compliance with the SVC characteristics. When the SVC is connected at power system (fig.6), the net capacitive reactive power Qc output of the SVC (vars generated by the SVC) was then constant at 12.87 Mvar.

Initially the Bypass breaker is closed and the resulting natural power flow at bus B8 is - 100 MW and - 22.127 Mvar; and the voltage is increased from 1.0159p.u to 1.0250p.u. The Vref of SVC connected at bus B8 is programmed at 1.0262p.u.

An initial reactive current injected corresponding to the natural power flow is 0.12873p.u. Then, the voltage profile and real power flow in power system transmission with SVC are increased in line 2; 3; and line 6, while reactive power flow in all transmission line is increased; which causes a decrease in congestion in the other line.

The increase in voltage buses and the reactive power led to decrease in congestion on bus 5 and bus 8.

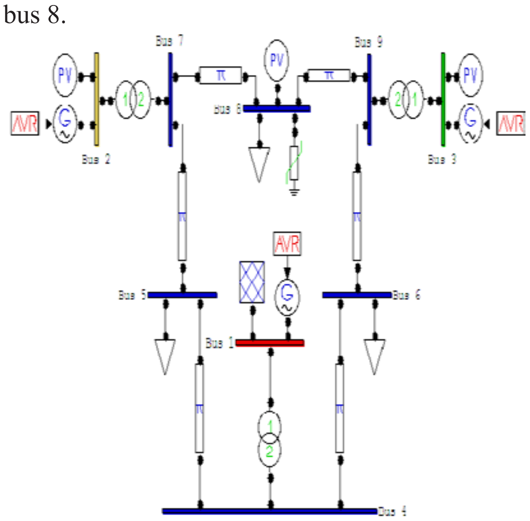

Figure 6. Installing SVC on WSCC (9-bus, 3-machine) power system.

This can be seen by the power variation at every bus. Relating to the total power results is transmission line; the total active power loss is decreased. The main concern lies at the SVC controllable region. The region defined in the graph is such that the SVC can only act under these conditions; the voltage levels were also increase so to meet the real power demand.

The results of OPF such as voltage profile, active and reactive power flow in transmission lines are analyzed and discussed. The effect of presence of SVC and effect of locations of SVC on buses of power system in magnitude voltage and angle voltage and active and reactive of power flow in transmission lines are investigated and results are analyzed.

Table 10. Real and Reactive Power Flow Results

From bus	To bus	Line	Active power flow (p.u)		Reactive power flow (p.u)	
			Without SVC	With SVC	Without SVC	With SVC
9	8	1	0.2418	0.2415	0.0312	- 0.0302
7	8	2	0.7638	0.7638	- 0.0079	- 0.0818
9	6	3	0.6081	0.6084	- 0.1807	- 0.1750
7	5	4	0.8662	0.8661	- 0.0838	- 0.0746
5	4	5	- 0.4068	- 0.4067	- 0.3868	- 0.3751
6	4	6	- 0.3053	- 0.3049	- 0.1654	- 0.1575
2	7	7	1.6300	1.6300	0.0665	0.0015
3	9	8	0.8500	0.8500	- 0.1086	- 0.1635
1	4	9	0.7164	0.7158	0.2704	0.2481
8	9	10	-	- 0.2407	-	- 0.1854

Table 10 shows the real and reactive power flow in transmission lines of power system. Results of simulation for real and reactive power flow at lines L1 to L9 of power system have been illustrated. In order to better understand the effect of location of installing SVC, Fig. 7, 8, 9 and fig.10 shows the variation of real and reactive power flow in transmission lines of system with and without SVC location.

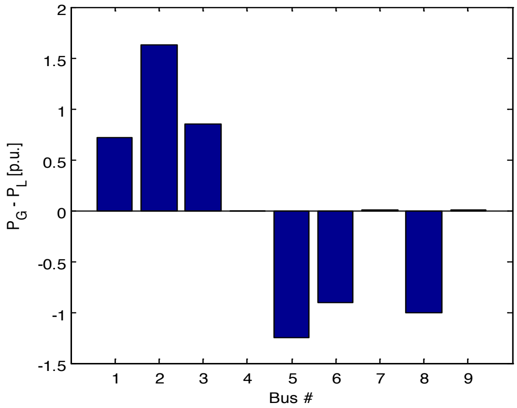

Figure 7. Real power flow in transmission lines without SVC

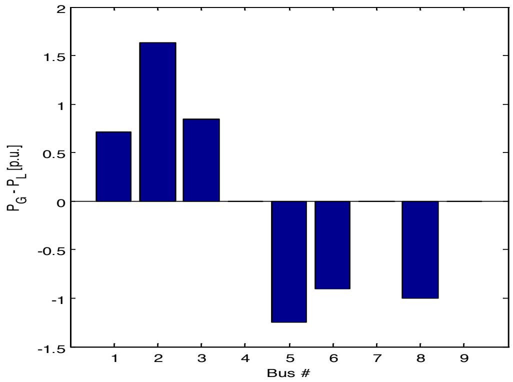

Figure 8. Real power flow in transmission lines with SVC

Voltage injection using SVC: The voltage is injected by increase in magnitude as well as angle to meet the characteristics as in Fig. 5. Considering SVC controllable region, during this mode the results get verified in accordance with Fig. 5. Also the voltage level increases sharply. This shows that the voltage profile of the system has gets better which increases the net power flow between transmission lines by injected reactive power.

Table 11 shows the magnitude voltage and phase voltage (or angle of voltage) at buses of power system. Magnitude of voltage at buses of power system for case study ate buses 1, to 9 of power system have been illustrated. In order to better understand the effect of location of installing SVC, Fig. 11 and fig. 12 shows the variation of magnitude of voltage at different busses of system with and without SVC location. Fig. 13 and fig. 14 shows the variation of angle of voltage at different busses of system with and without SVC location.

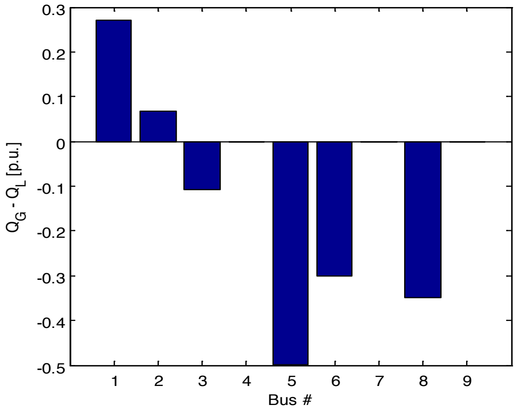

Figure 9. Reactive power flow in transmission lines without SVC

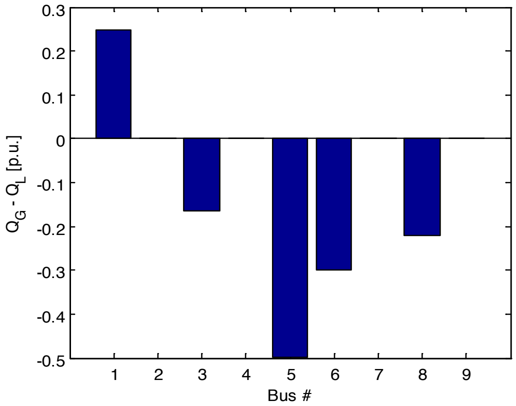

Figure 10. Reactive power flow in transmission lines with SVC

Table 11. Magnitude and Angle Voltage at Buses of System

Bus no.	MAG of Voltages (p.u)		Angle of Voltages (rad)	
	Without SVC	With SVC	Without SVC	With SVC
1	1.0400	1.0400	0.0000	0.0000
2	1.0250	1.0250	0.1619	0.1605
3	1.0250	1.0250	0.0814	0.0806
4	1.0258	1.0270	- 0.0387	- 0.0386
5	0.9956	0.9979	- 0.0696	- 0.0695
6	1.0127	1.0147	- 0.0643	- 0.0643
7	1.0258	1.0297	0.0649	0.0638
8	1.0159	1.0250	0.0127	0.0116
9	1.0324	1.0355	0.0343	0.0337

The harmonic distortion of the voltage is 2.55%. The harmonic orders 3 and multiples of 3 are virtually eliminated because the TCR is connected in a triangle (Delta). Shunt Reduced-order filters is placed on the power system with the SVC in order to better eliminate the 5th, 7th and 11th harmonics compensator. Other harmonics are negligible compared to the fundamental component.

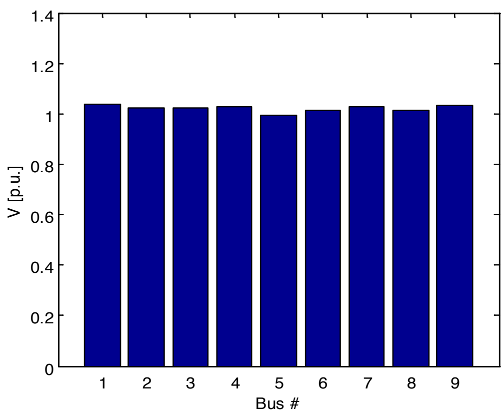

Figure 11. Voltage Buses without SVC

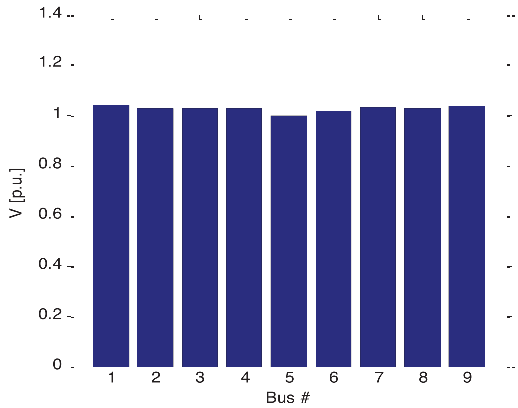

Figure 12. Voltage Buses with SVC

The increase in voltage buses and the reactive power led to decrease the total active power loss results in transmission line.

The results of power loss as real and reactive power are listed and descried as Table 12-13.

Table 12. Active and Reactive power Loss Results in ransmission Line without and with SVC

From bus	To bus	Line	Active power loss (p.u)		Reactive power loss (p.u)	
			Without SVC	With SVC	Without SVC	With SVC
9	8	1	0.00088	0.00072	- 0.21176	- 0.21573
7	8	2	0.00475	0.00468	- 0.11502	- 0.11764
9	6	3	0.01354	0.01348	- 0.31531	- 0.31747
7	5	4	0.02300	0.02287	- 0.19694	- 0.19954
5	4	5	0.00258	0.00249	- 0.15794	- 0.15929
6	4	6	0.00166	0.00163	- 0.15513	- 0.15583
2	7	7	0	0	0.15832	0.15805
3	9	8	0	0	0.04096	0.04179
1	4	9	0	0	0.03123	0.03057

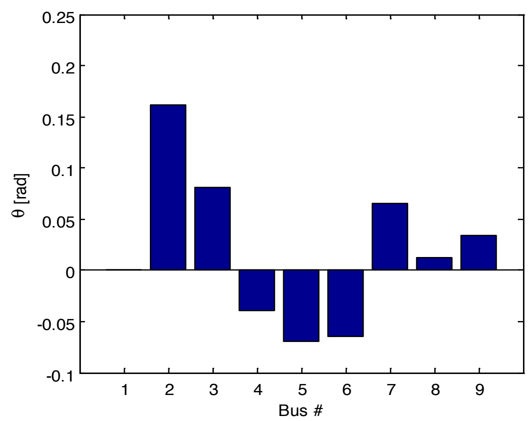

Figure 13. Teta angle of buses voltage without SVC

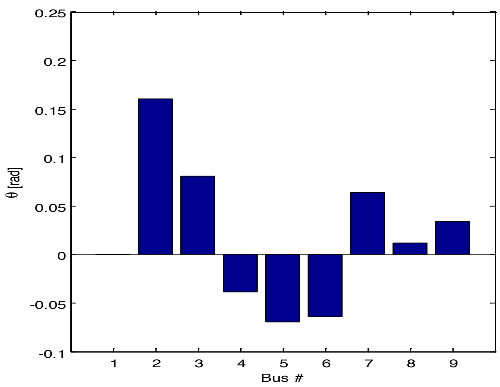

Figure 14. Teta angle of buses voltage with SVC

Table 13: Total power results in transmission line without and with SVC

Total Power	Total Load (p.u)	Total Generation (p.u)		Total Loss (p.u)	
		Without SVC	With SVC	Without SVC	With SVC
Real power	3.15	3,1964	3,1959	0,0464	0,0459
Reactive power	1.15	0,2284	0,2149	-0,9216	-0,9351

7. Conclusions

Congestion management is an important issue in deregulated power systems. FACTS devices such as SVC by controlling the voltage and reactive power in the network can help to reduce the flows in heavily loaded lines. Because of the considerable costs of FACTS devices, it is important to obtain optimal location for placement of these devices.

The results presented in this paper show the effect of SVC to maintain the voltage magnitude, reactive power control in power system transmission. Therefore, to control the power from one end to another end, this concept of reactive power flow control and voltage injection is applied. Modeling the system and investigating the results have given an indication that SVC are very useful when it comes to organize and maintain power system. Following conclusions are made:

- ✓ Power flow control is achieved and congestion is less.
- ✓ Transient stability is improved.
- ✓ Faster Steady State achievement.
- ✓ Improved Voltage Profile.

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