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Optimal Placement and Sizing of SVC for Voltage Security Enhancement

Shraddha Udgir
Department of Electrical Engineering
Madhav Institute of Technology & Science

Sarika Varshney
Department of Electrical Engineering
Madhav Institute of Technology & Science

Laxmi Srivastava
Department of Electrical Engineering
Madhav Institute of Technology & Science

ABSTRACT
In present day restructured power systems, increased transactions often lead to the situations where the system no longer remains in secure operating condition. To overcome such undesirable situation the Flexible AC transmission system (FACTS) controllers can be placed in a power system, which are able to provide fast and flexible control of voltage magnitude, active and reactive powers and to improve voltage security and stability. As investment cost of FACTS controllers is very high, these devices must be placed optimally in a power system. Static Var Compensators (SVC) is a shunt FACTS device that can be used for improvement of voltage profile in a power system. For optimal placement of SVC, this paper proposes a method that considers single line outage contingencies. On the basis of Voltage Performance Index two most critical contingencies are considered for searching the optimal location of SVC. The impact of SVC at selected optimal locations is evaluated and compared for varying load condition of the power system. The criteria for selection of optimal location consider improvement of the voltage profile and reduction in the system losses in a power system. The effectiveness of the proposed method is demonstrated on a standard IEEE 30-bus system.

General Terms
Contingency analysis, SVC, Line Losses

Keywords
Load flow analysis, FACTS devices, SVC, Voltage Performance Index, and Voltage Profile.

1. INTRODUCTION
Modern electric power system is facing many challenges due to the increase complexity in their operation and structure. In recent years, the stable operation of power systems has been a great concern for power system operators because of the limited transmission capacity of restructured power system [1]. The main reason for occurring voltage collapse is when the power system is heavily loaded, faulted and/or having shortage of reactive power [2]. The voltage collapse problem is closely related to the planning of reactive power particularly when the contingencies are considered [3]. Thus, the reactive power planning is one of the most crucial problems of a power system. When contingencies like line outage or generator outages occur, sometimes the power system becomes insecure from the viewpoint of bus voltage/ loading of transmission lines. During the outage conditions of some critical lines, generators are capable of supplying limited reactive power even sometimes the supplied reactive power cannot be used to fulfill the requirement of the network because the location is far from the generator point. Further, the flow of real power in transmission lines reduces the supply of reactive power demand of the system and creates voltage problems. Hence, the reactive power compensators are used to maintain the voltage profile and thereby to improve the performances of the power system [4].

The Flexible Alternating Current Transmission Systems (FACTS) devices are popularly used for improving the overall performance of a power system. FACTS devices are the solid state converters having capability of improving power transmission capacity, voltage profile, enhancing power system stability and security [5]. There are many reactive compensation devices used for reactive power compensation, each of which is having their own advantages and disadvantages. So it is necessary to select the most favorable device for compensation and placing it optimally [1].

A few research works has been done on FACTS controllers on improving the performance of power system by locating it optimally. F.D. Gailana in [6] proposes the comparison of various FACTS devices on behavior of power system. In [7] Gyugyi proposes the investment cost of FACTS controllers and their impact on power generation cost. The ref. [8] proposes a genetic algorithm based approach to determine the suitable types of FCATS devices and their optimal locations. In [9, 10], new SVC (a shunt compensation device) models and their implementation in Newton-Raphson load flow and optimal power flow algorithms has been is developed. The ref. [10] focuses on the placement of SVC to maintain the voltage profile of a power system under different contingencies. SVC is placed for improving the voltage profile while reducing the real power losses in the system. Optimal location of SVC for voltage security enhancement using MOPSO is discussed in [11].

2. FACTS DEVICES
The FACTS devices have become very popular for improving the overall performance of a power system. FACTS devices may series, shunt or combination of series-series or series-shunt deices. These devices provide direct and flexible control while transferring the power in steady state condition and reduces the power flows while the high speed commands gives the qualities to improve the dynamic stability. The optimal location of FCATS devices thus allow to increase the system loadability and the security margin [13].

In power system FACTS devices are used to achieve several goals. In a meshed network when steady state condition arises, the FACTS device supplies or absorbs reactive power. Thus, it increases or reduces voltage and controls the phase angle as well as the series impedance to permit the transmission line to operate near to their thermal limits and reduces the line flows. FACTS devices can be used for short circuits conditions as they limits the short circuit currents.

As shown in Fig. 1, the active power transmitted by a transmission line between bus i and bus j can be calculated as

$$P_{ij} = \frac{V_i V_j}{X_{ij}} \sin \delta_{ij}$$

Where V_i and V_j are the voltages at bus i and j ; X_{ij} is the reactance of the line ; δ_{ij} is the angle between V_i and V_j.

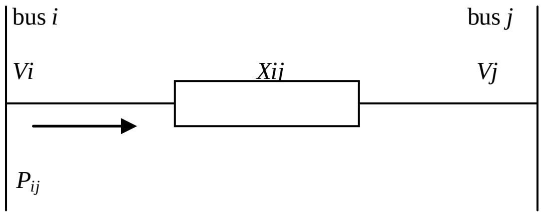

Figure 1. Power (P_{ij}) flow between buses i and j

Two models of SVC are usually implemented for load flow analysis of a power system [12].

2.1 SVC Susceptance model

In this model a changing susceptance B_{SVC} represents the fundamental frequency equivalent susceptance of all shunt modules making up the SVC. This model is an improved version of SVC models.

2.2 SVC Firing angle model

The changing firing angle α is a function of equivalent susceptance, B_{eq}. The model is made up of the parallel combination of thyristor controlled reactor (TCR) equivalent admittance and a fixed capacitive susceptance. This is a new and more advanced SVC representation. This model provides information on the SVC firing angle required to achieve a given level of compensation.

3. STATIC VAR COMPENSATOR

3.1 SVC Equivalent Susceptance Model

The growing power electronics technology and the control methods have made possible the development of fast SVC's in the early 1970's. The SVC consists of a group of shunt-connected capacitors and reactors banks with fast control action by means of thyristor switching circuits. For operating, the SVC can be considered as a variable shunt reactance that adjusts itself automatically according to the system operative conditions. According to nature of the equivalent SVC's reactance, i.e. capacitive or inductive, the SVC draws either capacitive or inductive current from the network. As this equivalent reactance of the connected SVC is suitably controlled, it allows the voltage magnitude to regulate at the connection point of SVC. The most popular configuration for continuously controlled SVC is the combination of either fix capacitor and thyristor controlled reactor or thyristor switched capacitor and thyristor controlled reactor. For steady-stale analysis, both the configurations can be modeled along similar lines [12, 14].

3.2 Modeling of SVC

Earlier the SVC model used for power flow analysis considered the SVC as a generator behind an inductive reactance while operating within limits. This reactance represents the SVC voltage regulation characteristic, i.e., SVC's slope X_{st} [2]. A simpler representation assumes that the SVC slope is zero for voltage regulation. This assumption may be acceptable as long as the Static Var Compensator is operating within limits, but if the SVC operates close to its reactive limits it may lead to gross errors [5]. The voltage-current characteristic of SVC is shown in Fig.2. The upper characteristic of the system are observed when low loading conditions are considered. If the slope is taken to be zero, then the generator will violate its minimum reactive limit, point $B_{X_{SL=0}}$. However, the generator will operate well within limits if the SVC slope is taken into consideration which is shown by point B [9, 12].

The SVC characteristic is represented by connecting the generator to an auxiliary bus coupled to the high-voltage bus by an inductive reactance which is equal to the per unit slope on the SVC slope. The auxiliary bus is represented as a PV-type bus whereas the high-voltage bus is taken as a PQ-type. When it operates outside the limits, then the generator representation becomes invalid. In such cases, it is necessary to change the SVC representation to a fixed reactive susceptance. This combined generator-susceptance model gives accurate results. However, both representations require a different number of buses. The generator uses two or three buses whereas the fixed susceptance uses only one bus.

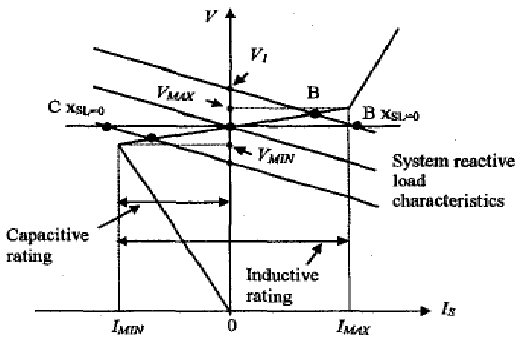

Figure 2 . Voltage- Current Characteristics of SVC

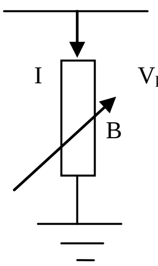

Figure 3. Variable Shunt Susceptance Model

While implementing this model for load flow analysis, it may require the Jacobian reordering and re-dimensioning during the iterative solution. Also it becomes necessary to verify whether or not the SVC can return to operate inside the limits. While operating outside the limits, it is important to model the Static Var Compensator as a susceptance and not as a generator set at its violated limit $Q_{voilated}$. If it is not set within the violated limits it will lead to inaccurate results. The reason is that the amount of reactive power drawn by the SVC is given by the product of the fixed susceptance, B_{fixed} and the nodal voltage magnitude V_k. A V_k is a function of network operating conditions as the amount of reactive power drawn by the fixed susceptance model may differ from the reactive power drawn by the generator model, i.e.

$$Q_{voilated} \neq -B_{fixed} V_k^2 \tag{1}$$

3.3 SVC Load Flow Models

The circuit shown in Fig. 3 is used to derive the SVC's nonlinear power equations and the linearised equations required by Newton's load flow method. In general, the transfer admittance equation for the variable shunt compensator is,

$$I_{svc} = j B_{SVC} V_K \tag{2}$$

And the reactive power equation is,

$$Q_k = - V_k^2 B_{SVC} \tag{3}$$

In SVC susceptance model the total susceptance B_{SVC} is taken to be the state variable, therefore the linearised equation of the SVC is given by

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & Q_k \end{bmatrix} \begin{bmatrix} \Delta\theta_k \\ \Delta B_{SVC} / B_{SVC} \end{bmatrix} \tag{4}$$

At the end of iteration i the variable shunt susceptance B_{SVC} is updated according to (5).

$$B_{SVC}^{(i)} = B_{SVC}^{(i-1)} + (\Delta B_{SVC} / B_{SVC})^{(i)} B_{SVC}^{(i-1)} \tag{5}$$

This changing susceptance value represents the total SVC susceptance which is necessary to maintain the nodal voltage magnitude at the specified value (1.0 p.u. in this paper).

4. PROBLEM FORMULATION

4.1 Nodal Voltage Magnitude Controlled by SVC

The variable shunt susceptance model is implemented in a Newton-Raphson load flow algorithm requires the incorporation of a nonstandard type of bus, namely *PVB*. This is a controlled bus where the nodal voltage magnitude and active and reactive powers are specified while the SVC's total susceptance B_{SVC} is handled as state variable. If B_{SVC} is within limits the specified voltage magnitude is attained and the controlled bus remains PVB-type. However, if B_{SVC} goes out of limits, the bus becomes PQ-type. In this situation, the SVC will act as an unregulated voltage compensator whose production or absorption reactive power capabilities will be a function of the nodal voltage at the SVC point of connection to get the voltage 1.0 p.u.

4.2 Transmission Losses Minimization

The proposed algorithm also considers the transmission loss minimization for selecting optimal location of SVC. Transmission loss minimization is responsible for the redistribution of the reactive power throughout the network, which in turn induces changes in the active power generated by the slack bus. It has been observed that if the network losses were reduced in only 0.15%, a more uniform voltage profile was observed at all the buses of a power system. The real and reactive power losses can be calculated using (6) and (7).

$$P_L = \sum_{k=1}^{nl} g_k \left[V_i^2 + V_j^2 - 2 V_i V_j \cos(\delta_i - \delta_j) \right] \tag{6}$$

$$Q_L = \sum_{k=1}^{nl} g_k \left[V_i^2 + V_j^2 - 2 V_i V_j \sin(\delta_j - \delta_j) \right] \tag{7}$$

Where *nl* is the number of transmission lines; g_k is the conductance of the *kth* line; $V_i\angle\delta_i$ and $V_j\angle\delta_j$ are the voltages at the end buses *i* and *j* of the *kth* line.

4.3 Voltage Deviations

In a power system, usually it is desirable to maintain the voltage deviations within ±5%. In this paper, the optimal location and size of SVC is determined by observing minimum value of voltage deviation (VD). Voltage deviation is calculated as follows:

$$VD = \sum_{i=1}^{NB} (1 - V_i) \text{ if } V_i < 1 \tag{8}$$

5. ALGORITHM FOR FINDING THE OPTIMAL LOCATION OF SVC

The following steps are implemented.

1. In the given power system, simulate various line outages and for each line outage run Newton-Raphson (NR) load flow method and calculate Voltage Performance Index (VPI) for each.
2. On the basis of VPI, rank the various contingencies in the order of their severity.
3. Consider the most severe contingency first and select the busses having low voltage magnitude.
4. Place SVC on these buses one by one starting from the bus with lowest voltage magnitude and analyze voltage profile, voltage deviations, real and reactive power losses.
5. On this basis, select the optimal location for the placement of SVC.
6. With SVC placed at this location, simulate various contingencies and examine the voltage profiles for each line outage.
7. With SVC at the selected location perceive its impact on power system by changing load in wide range.
8. Repeat steps 3 to 7 for second most severe contingency.

9. Find out the optimal location for the placement by comparing the voltage profile as obtained in steps 6 -8.

6. CASE STUDIES

The proposed algorithm for optimal placement and sizing of SVC has been implemented on IEEE 30 bus system [15]. This system comprises of one slack bus, 5 *PV* buses, 24 *PQ* buses and 41lines. For optimal placement of SVC, single line outage contingencies are simulated in the sample power system. The severity of a contingency is evaluated by using the VPI [16] as given by (9).

$$VPI = \sum_{i=1}^{NB} (\Delta|V_{i|}/\Delta\,|V_i^{max}\,|)^{2m} \qquad (9)$$

Where $\Delta|V_i|$ is the difference between the voltage magnitude for line outage condition and base case voltage magnitude; $\Delta|V_i^{max}|$ is the value set by the utility engineers indicating how much they wish to limit a bus voltage from changing on outage case.

It has been observed that NR load flow converges for 37 line outages out of 41 line outages. The VPI gives the idea about severity of a contingency. On the basis of VPI, the ranking order of severe contingencies in descending order is 36, 5, 9, 37, 26, 11 and so on. In this paper two most critical contingencies i.e. outage of line no. 36 and 5 have been considered for the placement of SVC.

6.1 Line Outages Contingency

The first case considered for placement of SVC is the line outage 36, which provides highest value of VPI and hence is the most severe contingency. To place an SVC optimally, this line outage condition has been analyzed in detail.

6.1.1 Impact of SVC at bus 30 with line outage 36

It is clear from Table 1 that the voltages at bus 30, 29, 27 and 26 are very low. These 4 buses are considered one by one for selecting optimal location of SVC. But due to limited space, the voltage profiles for line outage 36 with SVC placed at bus nos. 30 and 29 are shown in Table1. The developed load flow program also calculates the rating of SVC to maintain the voltage magnitude 1.0 p.u. at the connected bus. Table 2 depicts the performance of the power system with and without SVC. It includes rating of SVC to maintain the voltage magnitude 1 p.u., voltage deviations, and real and reactive power losses at the connected bus. It was found that the size of SVC at bus 29 was slightly smaller than at bus 30 but the voltage deviation, the real and reactive power losses at bus 29 was much greater than those with SVC at bus 30. The voltage deviation at bus 30 is 0.0653p.u. which is minimum of all the four cases. Hence, the optimal location for the placement of SVC may be bus 30 as far as the most critical line outage 36 is concerned.

6.1.2 Impact of SVC at bus 7 with line outage 5

The voltage profile for line outage 5 is shown in Table 3. It has been observed from table 3 that voltages at bus 7, 5 and 30 was very low. So, to place the SVC optimally, this line outage contingency is also analyzed. As we cannot connect SVC at bus 5 because it is a PV bus so the remaining two buses 7 and 30 are considered for the optimal location of SVC. The voltage profiles for the line outage 5 with SVC placed at bus 30 and bus 7 are shown in Table 3. The real and reactive power losses and SVC rating are shown in Table 4. In this line outage condition also the optimal location for the placement of SVC is found to be bus 30.

6.1.3 Impact of SVC at bus7 and 30 during load variation and line outage 36

It has been observed that when the load at various buses of the IEEE 30 bus system is varied randomly in wide range (.± 30%), the voltage profile of all the buses was good with SVC connected at bus 30. The lowest voltage which appears on bus 26 is 0.9948p.u. The voltage deviation with SVC at bus 30 is 0.0046 p.u. but the rating of SVC is -0.1106 which is higher as compared to that of contingency case. When the losses were considered then it was observed that the losses at bus 30 was lower than at bus 7. Table 5 and Table 6 show the voltage profile and performance for load variation on IEEE 30 bus system.

6.1.4 Impact of SVC at bus 7 during load variation and line outage 5

This case shows the effect of connecting SVC at bus 7 and 30 one by one when the load is varied (± 30%) and outage of line 5 occurs. The voltage profile observed on all the buses was good but not as good as the first case when the SVC was connected at bus 30. The voltage deviation is zero but the power losses are much more comparing when the load is varied at bus 30. The Table 7 and Table 8 show the voltage profile and performance observed for the system.

6.2 Comparison of both the cases for Line outage 36 and Line outage 5

When the line outages cases for the lines 36 and 5 were considered it was observed that the voltage profile was maintained when SVC was connected at bus 30. For line outage 36 the voltage profile was better than that for line outage 5, when SVC was connected at bus 7. The real and reactive losses, rating and voltage deviations for both the cases were analyzed for system. The voltage deviation for line outage 36 when SVC placed at bus 30 was 0.0493 p.u. and the real losses were 0.1272 and reactive losses were 0.2570 which is smaller than when the SVC is placed at bus 7. So in both the cases the bus 30 is the optimal location to place SVC to maintain the voltage profile of the power system.

6.3 Comparison for the cases when load is varied randomly

When the load variation is done randomly, the voltage profile of the buses with SVC connected at bus 30 and at bus 7 was computed. It was found that the voltages at bus 29 and 30 when SVC is placed at bus 7 were not good i.e.0.9952, 0.9796 p.u. But when these results are compared with the other case when SVC is connected at bus 30 the voltage are much improved as 1.011 and 1.00 p.u. the losses real and reactive were improved as for SVC at bus 30 it was 17.2360MW and 41.7615MVAR which are much less than that when SVC is placed at bus 7. The Table 9 and Figure 4 show and compare the voltage profile of the system with SVC at bus 7 and bus 30. From these, bus 30 is found to be the optimal location for SVC to improve voltage profile and to reduce losses,

7. CONCLUSION

In this paper, a method for optimal placement and sizing of SVC has been proposed for improving the voltage profile and reducing the system losses in a power system. On the basis of VPI two most critical contingencies and two optimal locations of SVC were selected. With SVC connected on the selected buses, their impact on power system under single line outages and random load variation in wide range has been analyzed and compared for the selection of optimal location of SVC for a power system. Though the proposed approach has been implemented on IEEE 30 bus system, the same can be implemented on practical power systems as well.

Table 1 Voltage profile of IEEE 30 bus system with and without SVC for line outage 36

	Line outage 36		
Bus number	**Without SVC**	**With SVC at bus 30**	**With SVC at bus 29**
1	1.06	1.06	1.06
2	1.043	1.043	1.043
3	1.0186	1.021	1.021
4	1.0093	1.0123	1.0122
5	1.01	1.01	1.01
6	1.0095	1.0122	1.0122
7	1.0019	1.0036	1.0035
8	1.01	1.01	1.01
9	1.0374	1.0513	1.0511
10	1.0184	1.0457	1.0452
11	1.082	1.082	1.082
12	1.0481	1.058	1.0578
13	1.071	1.071	1.071
14	1.0292	1.0427	1.0424
15	1.0196	1.0364	1.036
16	1.0282	1.0455	1.0452
17	1.0159	1.0403	1.0399
18	1.0068	1.0275	1.0271
19	1.0024	1.0254	1.025
20	1.0056	1.0297	1.0293
21	1.0022	1.0319	1.0314
22	1.0017	1.032	1.0314
23	0.9957	1.0221	1.0214
24	0.9729	1.0121	1.0109
25	0.9135	0.9925	0.9898
26	0.8938	0.9744	0.9716
27	0.8884	0.9928	0.9891
28	1.0137	1.0158	1.0158
29	0.8651	0.991	1
30	0.8517	1	0.9748

Table 2 Performance of IEEE 30-Bus System With and Without SVC for line outage 36

Bus Number	**Without SVC**	**With SVC**	
		at 30	**at 29**
SVC Rating (p.u.)	-	-0.1206	-0.1158
Real Power Losses(p.u.)	0.179	0.1381	0.1383
Reactive Power	0.4877	0.2789	0.2795

Table 3 Voltage profile on IEEE 30 bus system with SVC for line outage 5

	Line outage 5		
Bus Number	**Without SVC**	**With SVC at bus 30**	**With SVC at bus 7**
1	1.06	1.06	1.06
2	1.043	1.043	1.043
3	1.0109	1.0154	1.0157
4	1.0009	1.0064	1.0067
5	0.9318	1.01	1.01
6	0.9988	1.0071	1.0076
7	0.9596	0.9964	1
8	1.01	1.01	1.01
9	1.0434	1.0481	1.0481
10	1.0358	1.0408	1.0407
11	1.082	1.082	1.082
12	1.0523	1.0554	1.0553
13	1.071	1.071	1.071
14	1.0369	1.0404	1.0403
15	1.0315	1.0353	1.0351
16	1.0379	1.0418	1.0418
17	1.031	1.0357	1.0356
18	1.0207	1.0251	1.0249

19	1.0175	1.0221	1.0219
20	1.0213	1.026	1.0258
21	1.0234	1.0287	1.0284
22	1.024	1.0294	1.029
23	1.02	1.0248	1.0242
24	1.0131	1.0191	1.018
25	1.0091	1.0179	1.0149
26	0.9912	1.0003	0.9972
27	1.0152	1.0257	1.0215
28	1.006	1.0074	1.0073
29	0.9952	1.0086	1.0017
30	0.9836	1	0.9902

Table 4 Performance of IEEE 30-Bus System With SVC for line outage 5

Bus number	With SVC at bus 30	With SVC at bus 7
Real power losses (p.u.)	0.0362	0.0397
Reactive power losses (p.u.)	0.0564i	0.0618i
SVC rating (p.u.)	-0.0153	-0.0655

Table 5 Voltage Profile of IEEE 30 bus system for Load Variation with line outage 36

Bus number	SVC at bus 7	SVC at bus 30
1	1.06	1.06
2	1.043	1.043
3	1.025	1.021
4	1.0117	1.0123
5	1.01	1.01
6	1.0113	1.0122
7	1	1.0036
8	1.01	1.01
9	1.0533	1.0513
10	1.0493	1.0457
11	1.082	1.082
12	1.0531	1.058
13	1.071	1.071
14	1.039	1.0427
15	1.0357	1.0364
16	1.0262	1.0455
17	1.0077	1.043
18	1.0284	1.0275
19	1.0272	1.0254
20	1.032	1.0297
21	1.0366	1.0319
22	1.037	1.032
23	1.0269	1.0221
24	1.0235	1.0121
25	1.0198	0.9925
26	1.0022	0.9744
27	1.0261	0.9928
28	1.0103	1.0158
29	1.0063	0.991
30	0.9949	1

Table 6 Performance of IEEE 30-Bus System With SVC for Load Variation and line outage 36

SVC rating(p.u.)	0.0617	-0.1106
deviation	0.048	0.0046
Real power loss(p.u.)	0.0441	0.0404
Reactive power loss (p.u.)	0.0891i	0.0816i

Table 7 Comparison of Voltage Profile of IEEE 30 bus system Load Variation and line outage 5

Bus number	SVC at bus 7	SVC at bus 30
1	1.06	1.06
2	1.043	1.043
3	1.0155	1.0152
4	1.0065	1.0061
5	1.01	1.01
6	1.0073	1.0067
7	1	0.9962
8	1.01	1.01
9	1.0479	1.0479
10	1.0405	1.0406
11	1.082	1.082
12	1.0552	1.0552
13	1.071	1.071
14	1.0402	1.0403
15	1.035	1.0352
16	1.0416	1.0417
17	1.0354	1.0356
18	1.0247	1.0249
19	1.0218	1.0219

20	1.0257	1.0258
21	1.0282	1.0285
22	1.0288	1.0292
23	1.024	1.0246
24	1.0179	1.019
25	1.0146	1.0177
26	0.9969	1.0001
27	1.0213	1.0256
28	1.0071	1.0071
29	1.0014	1.0085
30	0.9899	1

Table 8 Performance of IEEE 30-Bus System With SVC during Load Variation

SVC rating (p.u.)	-0.0698	-0.0158
Real power losses (p.u.)	0.441	0.0404
Reactive power losses (p.u.)	0.0891i	0.0816i

Table 9 Comparison of Voltage Profiles of IEEE 30 bus during Load Variation

Bus number	SVC at bus 7	SVC at bus 30
1	1.06	1.06
2	1.043	1.043
3	1.0191	1.0221
4	1.012	1.0136
5	1.01	1.01
6	1.0096	1.0122
7	1	1.0035
8	1.01	1.01
9	1.0475	1.0526
10	1.385	1.0476
11	1.082	1.082
12	1.0542	1.0604
13	1.071	1.071
14	1.0397	1.0451
15	1.0333	1.0404
16	1	1.0489
17	1.0341	1.0435
18	1.0226	1.03
19	1.0192	1.0275
20	1.023	1.0319
21	1.0247	1.0342
22	1.0254	1.035
23	1.022	1.0299
24	1.0142	1.0241
25	1.009	1.0245
26	0.9883	1.0121
27	1.0158	1.0307
28	1.0075	1.0111
29	0.9901	1.0112
30	0.9754	1

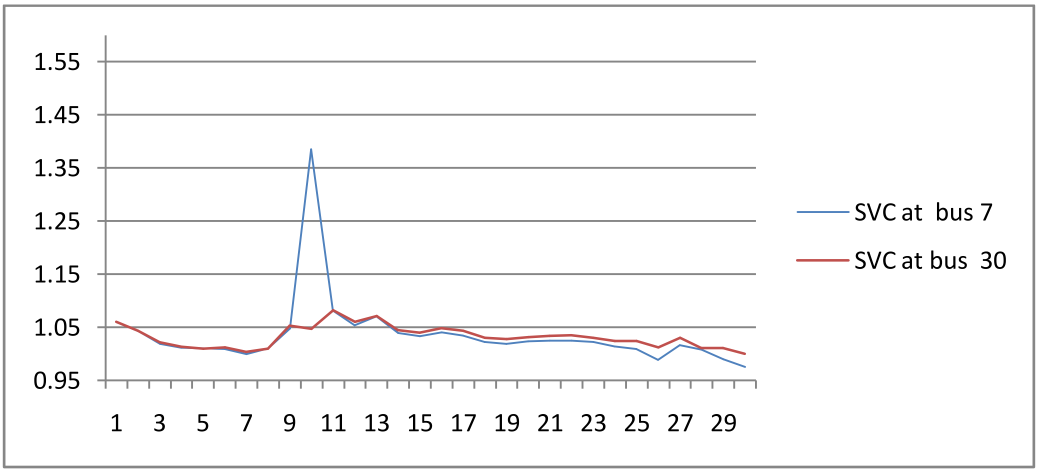

Figure 4. Voltage deviation when randomly the load is varied

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