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Integration Static Var Compensator in Power System for Voltage Stability Improvement using Straight Variation Approach

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ABSTRACT— ***This paper deals with a novel approach for studying the impact of Static VAR compensators in power system to improve voltage profile. Because of the increased energy demand, transmission and distribution networks are overloaded which may cause voltage reduction problems. Allocation of FACTS device mainly SVC can be done for the improvement of voltage by identifying the weak bus using straight variation approach. This method is implemented using MATLAB-PSAT and is tested on IEEE 14 bus networked system at different loading conditions. The results demonstrate the improvement in voltage profile at different loads.***

Keywords— FACTS devices, Static VAR Compensator (SVC), Voltage profile, Straight Variation approach, PSAT

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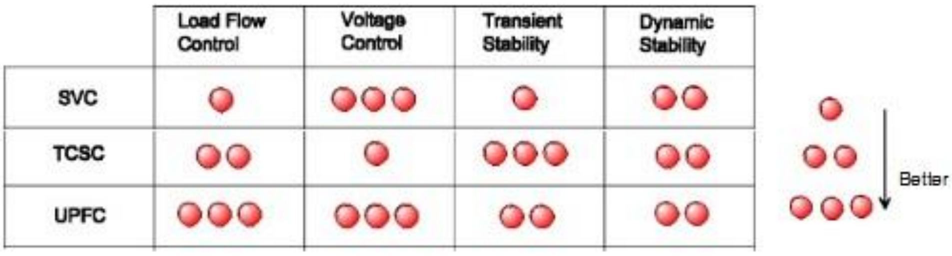
1. INTRODUCTION

The life style of man changes day by day. Electricity is essential for improving the life style. This increases the overall demand of electricity and this increases the loading of existing power transmission systems, operation of power system becomes more complex and less stable. For better utilization of existing power system it is necessary to install FACTS devices to increase the power transfer capability [1]. The transmission line variables line impedance, terminal voltage magnitude and angle can be controlled by FACTS devices in an effective manner [2]. This helps to improve the system dynamic behavior and hence the system reliability. The main function of these devices is to control the power flows[3]. The allocation of FACTS device is important in the proper operation and control of the network to meet the increased load demand.



	Load Flow Control	Voltage Control	Transient Stability	Dynamic Stability
SVC	●	●●●	●	●●
TCSC	●●	●	●●●	●●
UPFC	●●●	●●●	●●	●●

Figure 1: Performance of FACTS devoices

Many researches were made different methods like Genetic Algorithm, Particle Swam Optimization were used for the allocation of FACTS devices [4, 5, 6].

Static Var Compensator, Thyristor Controlled Series Compensator and Unified Power Flow Controller are the different types of FACTS devices. The better performance of these for certain functions are as follows.

The Figure 1 shows the different performance of FACTS devices in Steady state, dynamic and transient responses[7].

The voltage stability is highly dependent to the reactive power. Some of the loads absorb and some others generate reactive power. The load varies very rapidly which will result in voltage amplitude variation. The rapid operation of SVC will solve this issue by injecting and consuming reactive power which is just opposite to that of loads[8,9]. Thus it can maintain a smooth voltage profile. In this paper we modeled the reactive power as an ideal reactive power injector or consumer at a bus.

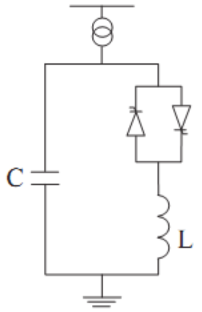


Figure 2: Basic SVC topology

Figure 2 shows the basic SVC topology and SVC modeled here as a shunt connected device whose basic reactive power injection equation is given by[10],

$$\Delta Q_i = Q_{svc} \qquad \text{(I.1)}$$

The anti-parallel thyristor switch will determine whether the reactive power is to be injected or absorbed.

This paper mainly concerned with the voltage profile by allocation of SVC in IEEE 14 bus system for different loading conditions.

2. METHODOLOGY

Most of the studies for allocation of SVC in network were made by defining Voltage Stability Index along with load flow analysis[11]. In this paper a new approach is made to identify the weak bus for allocating SVC. This simple Straight variation calculation approach is used to improve the voltage profile of the system.

2.1 Straight Variation Approach

It is an easy method to identify the weak bus in a system using a multiplication factor index. As load changes the voltage profile also change. This change will not be uniform for all buses. In some buses the voltage change will be large where as in some other buses it may less.

2.2 PSAT Software

It is an open source power system analysis toolbox for Matlab and GNU/Octave developed by Dr. Federico Milano. It can be used for power system analysis and control learning, education and research. PSAT is a Matlab toolbox for electric power system analysis and control. The command line version of PSAT is also GNU Octave compatible. PSAT includes power flow, continuation power flow, optimal power flow, small signal stability analysis and time domain simulation. All operations can be assessed by means of graphical user interfaces (GUIs) and a Simulink-based library provides an user friendly tool for network design.

Newton-Raphson algorithms for solving the power flow problem are described in many books and papers. At each iteration the Jacobian matrix is updated and the following linear problem is solved:

$$\begin{bmatrix} \Delta x^i \\ \Delta y^i \end{bmatrix} = -\begin{bmatrix} F_x{}^i & -F_y{}^i \\ G_x{}^i & G_y{}^i \end{bmatrix}^{-1} \begin{bmatrix} f^i \\ g^i \end{bmatrix} \qquad \text{(II.1)}$$

$$\begin{bmatrix} x^{i+1} \\ y^{i+1} \end{bmatrix} = \begin{bmatrix} x^i \\ y^i \end{bmatrix} + \begin{bmatrix} \Delta x^i \\ \Delta y^i \end{bmatrix} \qquad \text{(II.2)}$$

Consider a single-machine PV bus as shown in Fig. 3 This bus supplies a PQ load of constant power factor through a transmission line. The state vector x in equation II.3 represents the voltage (V), and the power angle (δ) and parameter vector λ represent the real and reactive power.

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = \begin{bmatrix}J_{P\theta} & J_{PV}\\ J_{Q\theta} & J_{QV}\end{bmatrix}\begin{bmatrix}\Delta\theta\\ \Delta V\end{bmatrix} \qquad \text{(II.3)}$$

Where,

ΔP: the incremental change in bus real power
ΔQ: the incremental change in bus reactive power
ΔV: the incremental change in bus voltage magnitude
$\Delta\theta$: the incremental change in bus voltage angle
J: the Jacobian matrix.

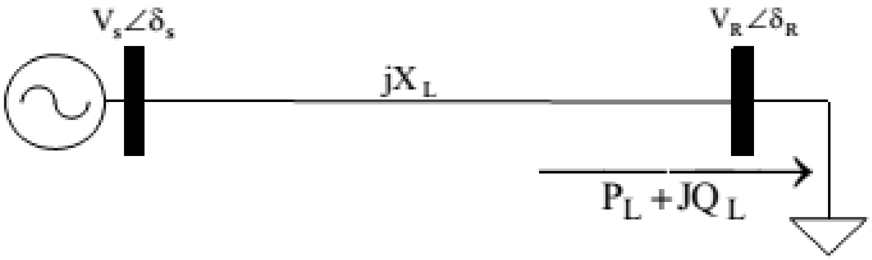


Figure 3: Single-machine PV bus supplying a PQ load bus

3. SIMULATION RESULTS

The simulations were performed using MATLAB-PSAT background for IEEE 14 bus system. The single line diagram of IEEE 14 bus test system is shown in Figure 4 which encompasses 5 generator buses, 9 load buses and 20 transmission lines.

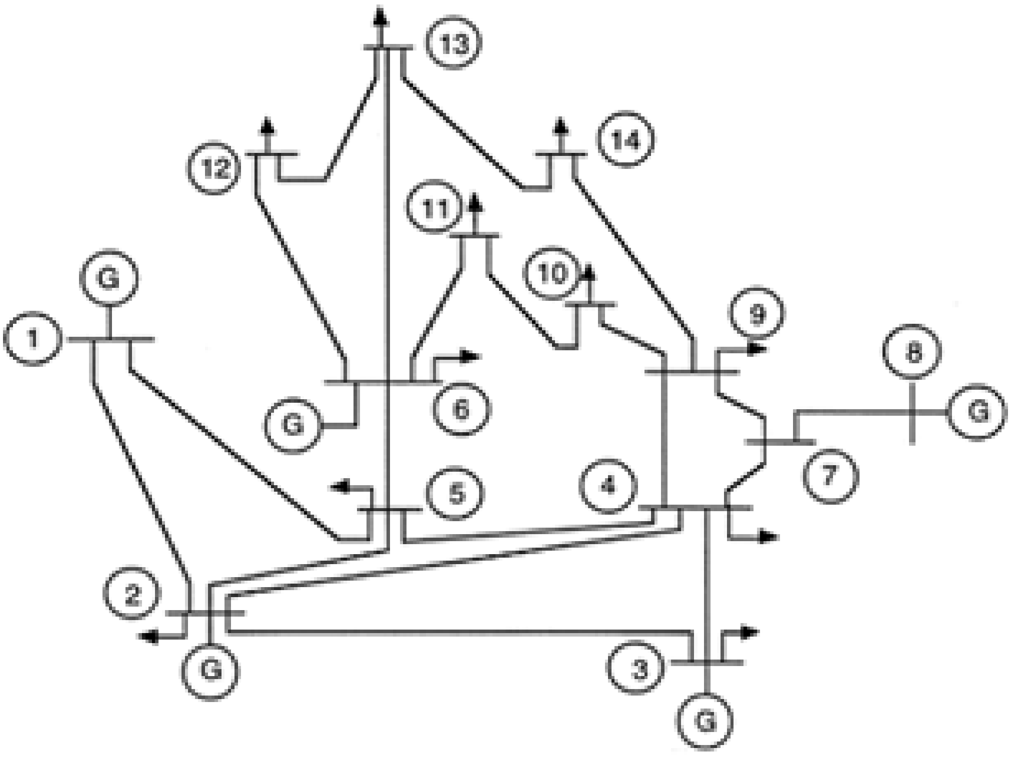


Figure 4: IEEE 14 bus test system

The base MVA for IEEE 14 bus test system is taken as 100MVA. The total generation real power is 272.4 MW and reactive power -16.99MVar and 95.4 MVar. The bus data and the line data of IEEE 14 bus system are as follows. The bus data is given in the Table 1.

Table 1: Bus Data of IEEE 14 Bus system

Bus No	Bus Code	Voltage Magnitude	Voltage angle	Load		Generator				Injected Mvar
				MW	Mvar	MW	Mvar	Q_{min}	Q_{max}	
1	1	1.06	0	0	0	232.4	-16.9	0	0	0
2	2	1.01	0	21.7	12.7	40	42.4	0	20	0
3	2	1.07	0	14.2	19	0	23.4	0	20	0
4	2	1.09	0	11.2	7.5	0	12.2	0	20	0
5	2	1	0	0	0	0	17.4	0	20	0
6	0	1	0	47.8	3.9	0	0	0	0	0
7	0	1	0	7.6	1.6	0	0	0	0	0
8	0	1	0	0	0	0	0	0	0	0
9	0	1	0	29.5	16.6	0	0	0	0	0
10	0	1	0	9	5.8	0	0	0	0	0
11	0	1	0	3.5	1.8	0	0	0	0	0
12	0	1	0	6.1	1.6	0	0	0	0	0
13	0	1	0	13.5	5.8	0	0	0	0	0
14	0	1	0	14.9	5	0	0	0	0	0

The Line Data of IEEE 14 Bus system is as in the Table 2. The load flow is performed using the emerging software PSAT for an IEEE-14 bus test system.

Table 2: Line Data of IEEE 14 Bus system

From Bus	To Bus	Line Resistance R	Line Reactance X	Line Susceptance 1/2 B	Tapping
1	2	0.01938	0.05917	0.0264	1
2	3	0.04669	0.19797	0.0219	1
2	6	0.05811	0.17632	0.0187	1
1	7	0.05403	0.22304	0.0246	1
2	7	0.05695	0.17388	0.017	1
3	6	0.06701	0.17103	0.0173	1
6	7	0.01335	0.04211	0.0064	1
7	4	0	0.25202	0	0.932
6	8	0	0.20912	0	0.978
8	5	0	0.17615	0	1
6	9	0	0.55618	0	0.969
8	9	0	0.11001	0	1
9	10	0.03181	0.0845	0	1
4	11	0.09498	0.1989	0	1
4	12	0.12291	0.25581	0	1
4	13	0.06615	0.13027	0	1
9	14	0.12711	0.27038	0	1
10	11	0.08205	0.19207	0	1
12	13	0.22092	0.19988	0	1
13	14	0.17093	0.34902	0	1

To study the effect of voltage profile in buses with increase in load is done by using a factor known as Load Multiplication Factor. The Load Multiplication Factor values and the corresponding voltage variations in pu for all buses are observed and they are shown in the Table 3.

Table 3: Voltage Profile at weak buses

Bus	Load Multiplication Factor			
	1	1.5	2	2.3
Bus 01	1.060	1.060	1.060	1.060
Bus 02	1.045	1.045	1.045	1.045
Bus 03	1.010	1.010	1.010	1.010
Bus 04	1.012	0.994	0.971	0.954
Bus 05	1.016	0.999	0.977	0.960
Bus 06	1.070	1.070	1.070	1.070
Bus 07	1.049	1.032	1.012	0.997
Bus 08	1.090	1.090	1.090	1.090
Bus 09	1.033	1.008	0.978	0.958
Bus 10	1.032	1.007	0.978	0.959
Bus 11	1.047	1.033	1.016	1.005
Bus 12	1.053	1.044	1.034	1.028
Bus 13	1.047	1.034	1.020	1.010
Bus 14	1.021	0.991	0.957	0.934

BUS 14, 9 and10 are identified as weak bus for the placement of SVC. The variation of pu voltage at each weak bus can be identified from the following graph (Figure 5).

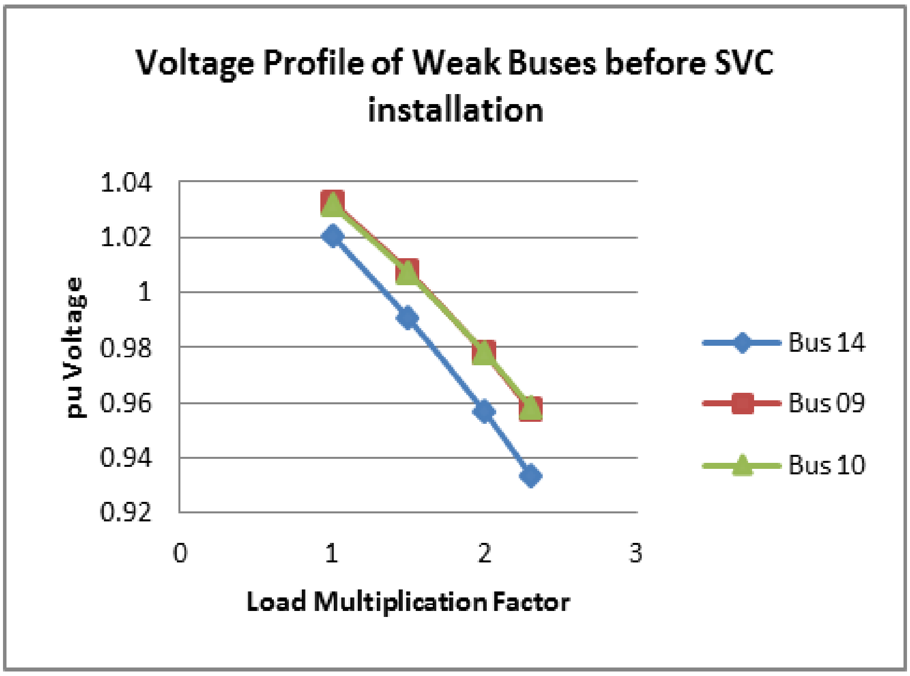


Figure 5: Change in voltage before SVC installation

pu Voltage for a load multiplication factor 2.3 is 0.934 at Bus 14 and it needs reactive power to improve the voltage. So Bus 14 is selected as the weakest bus for placement of SVC. After placement SVC the Voltage Profile of the test system is analyzed and it is shown in Table 4.

Table 4: Voltage Profile at weak buses after SVC installation

Bus	**Load Multiplication Factor**			
	1	**1.5**	**2**	**2.3**
Bus 01	1.060	1.060	1.060	1.060
Bus 02	1.045	1.045	1.045	1.045
Bus 03	1.010	1.010	1.010	1.010
Bus 04	1.019	1.006	0.989	0.976
Bus 05	1.024	1.012	0.996	0.984
Bus 06	1.070	1.070	1.070	1.070
Bus 07	1.041	1.032	1.020	1.012
Bus 08	1.090	1.090	1.090	1.090
Bus 09	1.011	0.998	0.983	0.973
Bus 10	1.014	0.999	0.983	0.972
Bus 11	1.038	1.029	1.019	1.012
Bus 12	1.047	1.042	1.037	1.033
Bus 13	1.042	1.036	1.031	1.027
Bus 14	1.000	1.000	1.000	1.000

The variation of pu voltage at each bus after SVC installation can be simply identified from the following graph (Figure 6).

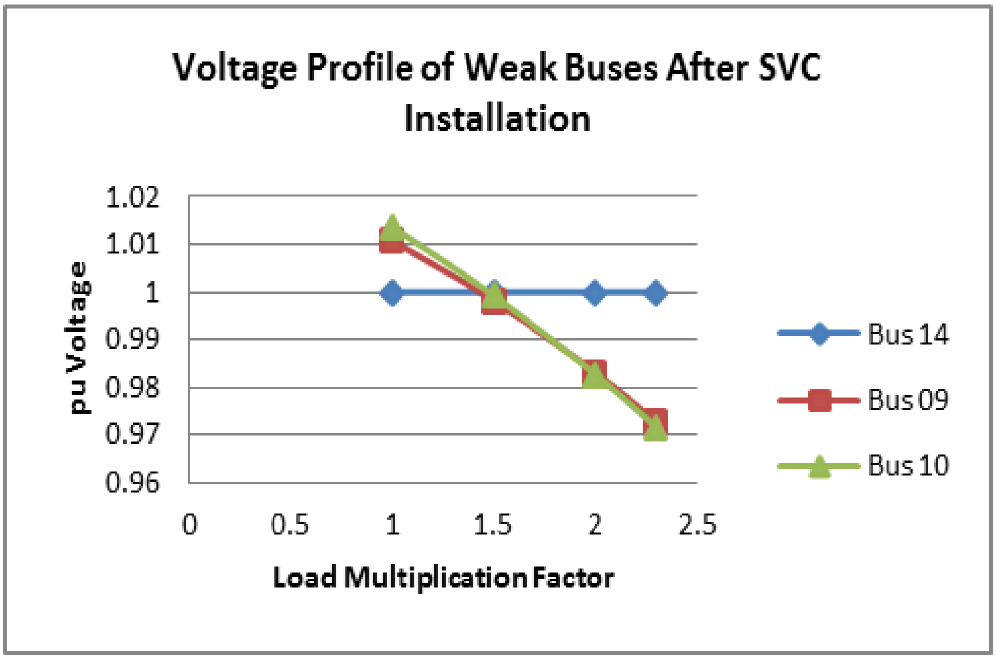


Figure 6: Change in voltage after SVC installation

A compairison is made to analyse the performance of voltage profile of the system before and after SVC placement.

4. CONCLUSION

This paper presents a method to allocate SVC in network system and analyse the performance of voltage profile using an efficient simple Straight Variation Approach. The method described in this paper is tested for IEEE 14 bus test system and the results are obtained. The weakest Bus in IEEE 14 bus test system is Bus number 14 and the pu voltage variation before and after SVC installation is analysed. It was observed that the voltage profile at weakest bus is found to be improved. Also the bus voltage remain stable. Here the size of SVC is fixed. It is observed that the voltage levels are improved and are within the limit. Here the method gives only the magnitude. The voltage angle also should be considered for the entire system stability analysis. Multi-type FACTS devices are also integrated to the system for secure, reliable network. These can be used as a better alternative for future studies.

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