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Voltage Stability Enahncement using Static VAR Compensator (FC-TCR)

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Abstract— One of the major concerns of power system stability is the voltage instability. The main reason behind the voltage instability is the deficit of the reactive power in the system. The effect of Static VAR Compensator (SVC) in static voltage stability enhancement will be studied in this paper. Improving the systems voltage by increasing the reactive power handling capacity of the system by using SVC during a large disturbance is the area of study. The IEEE-14 bus system is used as the test system for the study. The simulations are carried out by using MATLAB/PSAT software. The simulation results show the effectiveness of SVC to improve the voltages when connected to the system.

Index Terms— FACTS, SVC,Voltage Stability, PSAT.

1 Introduction

Demand is rising and the modern society would cease to function without access to electricity. As the volume of power transmitted and distributed increases, so do the requirements for high quality and reliable supply [1]. Thus the Transmission networks of present power systems are becoming progressively more stressed because of increasing demand and limitations on building new lines. Making existing lines as well as new ones more efficient and economical becomes a compelling alternative [1].

Present day power systems are being operated closer to their stability limits due to economic and environmental constraints. Maintaining a stable and secure operation of a power system is therefore a very important and challenging issue. Voltage instability has been given much attention by power system researchers and planners in recent years, and is being regarded as one of the major sources of power system insecurity [2].

The main factor causing voltage instability in a power system is lack of reactive power in the system. The solution to this problem is Flexible AC Transmission System (FACTS), which involves up-gradation of the transmission lines by installing FACTS devices. Since blackouts in the majority of cases are caused by a deficit of reactive power, FACTS comes into the picture as a remedy in a natural way [3].

Voltage stability problems arising from a large disturbance categorized under large disturbance voltage stability are a major concern in power systems stability [3]. This is the study made in this paper. Large-disturbance voltage stability refers to the system's ability to maintain steady voltages following large disturbances such as system faults, loss of generation, or, circuit contingencies [3].

The voltages at various points after such a disturbance may reach the pre-disturbance values or not, leading to voltage sag at certain points. Using FACTS controllers one can control the variables such as voltage magnitude and phase angle at chosen bus and line impedance where a voltage collapse is observed [4].

3 Problem Statement

Voltage stability is the ability of a power system to maintain acceptable voltages at all buses in the system under normal conditions and after being subjected to a disturbance [5]. It is the main factor that limits the amount power transfer in a system. Voltage instability typically occurs in the system which is heavily loaded, faulted or has reactive power shortage [5]. The large disturbance considered here is a three phase fault, typically a transmission line loss or a transmission line outage. The fault is observed at the transmission line between bus2 and bus 5 in a 14 bus system with a fault time of 1.2 seconds and the fault clearing time of 1.209 seconds. Due to this fault there is a voltage sag in the number of buses namely bus 4, 5, 7, 9, 10,14. It is observed from the figure1 which shows the sag in the voltage magnitude profile of the buses when subjected to a large disturbance, which in this case is a transmission line outage.

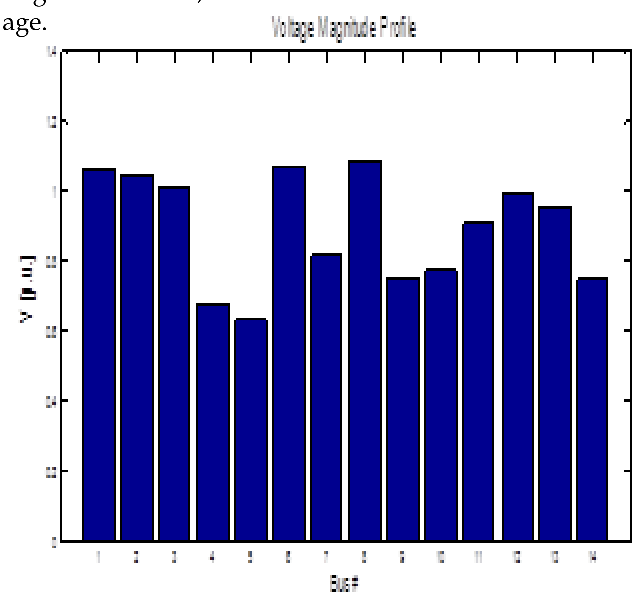

Fig1: voltage magnitude profile during three phase fault.

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The idea behind this work is to improve the voltage magnitude profile of the system and increase the maximum loading capacity by using reactive power compensation at the buses.

3 Static VAR Compensator

Static VAR compensator (SVC) is a shunt connected static electrical device. It acts as a generator or absorber of reactive power. SVC has its output adjusted to exchange capacative or inductive current according to the requirement of the system. The main function of SVC is to regulate the voltage by providing fast acting reactive power. They generate or absorb reactive power at its point of connection in the power system.
The basic structure of SVC is shown in figure 2. It can be seen that the model of a SVC is represented by an inductor connected in series to a bi-directional thyristor and a fixed capacitor connected in parallel. Through a suitable coordination of the capacitors and the thyristor controlled reactor (TCR), the bus reactive power injected (or absorbed) by the SVC can be continuously varied in order to control the voltage or to maintain the desirable power flow in the transmission system [4].
The amount of current in the reactor can be varied by varying the delay angle of the thyristors. When the capacitive and inductive currents become equal, both the VARs cancel out and give zero VAR output, which indicates that there is no power exchange between the SVC and the AC system [6].

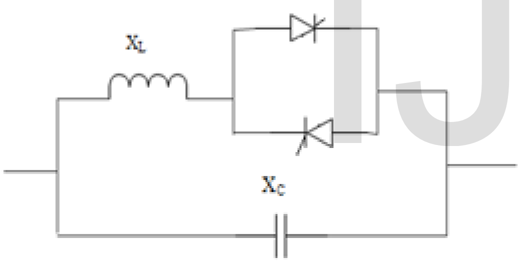

Fig 2: Structure of SVC

Figure 3 shows the V-I characteristics of SVC, which has a capacitive limit and an inductive limit. At the capacitive limit the SVC becomes a shunt capacitor and at the inductive limit the SVC becomes a shunt reactor.

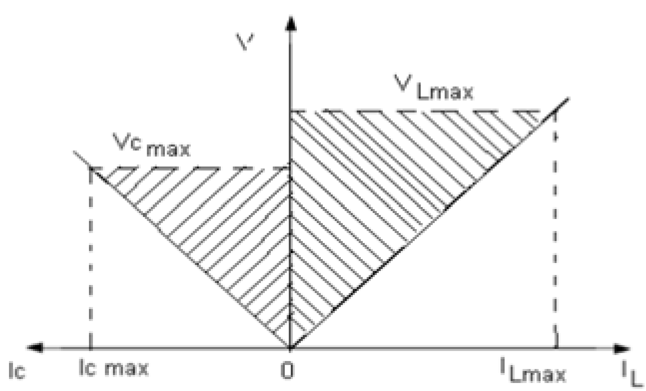

Fig 3: V-I characteristics of SVC.

4 Test System and Software

A standard IEEE 14 bus system as shown in figure 4 is used for the study. The test system consists of five generators and eleven PQ bus (or load bus) [7]. The simulations are done using PSAT simulation software. PSAT is a power System Analysis software, which has many features including power flow and continuation power flow [8]. Voltage stability of the test system is investigated using Continuation power flow, a feature of PSAT. The figure 4 shows the PSAT model of IEEE 14 bus system.

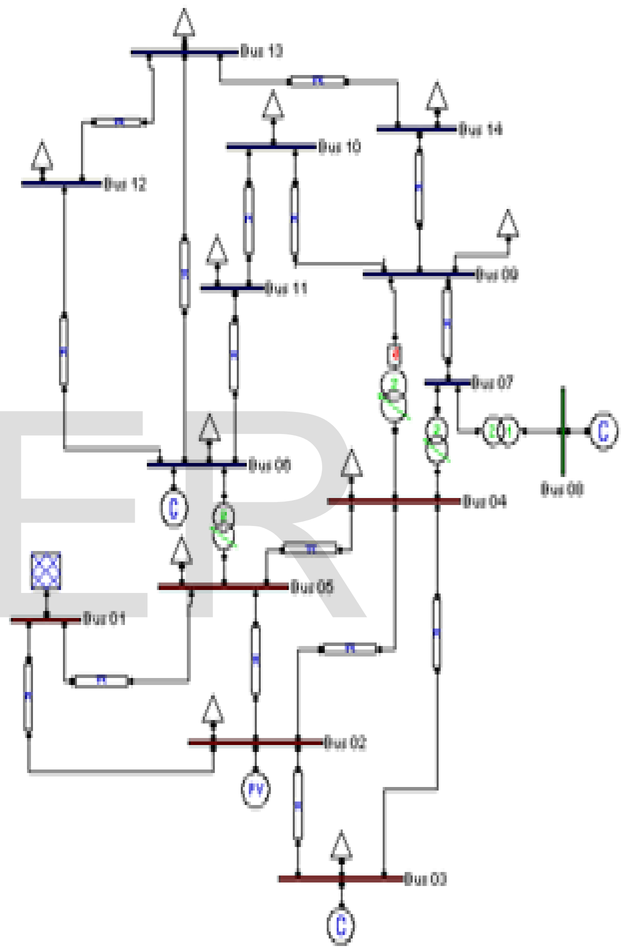

Fig 4: PSAT model of IEEE 14 bus system.

5 Result and Discussion

The power flow analysis using PSAT is run for the test systems and the voltage profile is obtained. The test systems are simulated for a base case of 100 MVA. The figure 5 shows the voltage magnitude profile of the 14 bus system for base case. Then a three phase fault is introduced in the system as discussed earlier, which is basically a transmission line outage. The figure 1 shows the voltage magnitude profile obtained after the fault has been introduced in the system.

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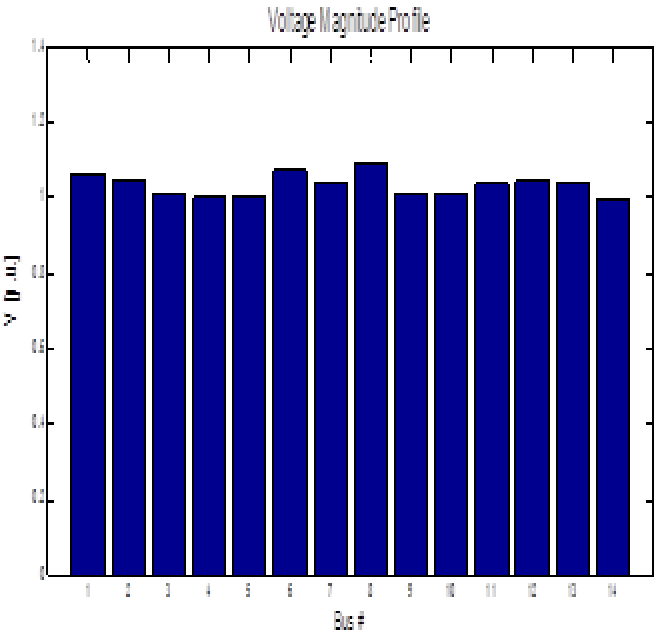

Fig 5: voltage magnitude profile of the 14 bus system for base case.

There is a considerable drop in the voltage magnitude in number of buses which is clear from figure 1 and figure 5. So we need to make reactive power compensation to improve the voltage profile at these buses by using SVC [2]. Thus it is required to find out the best location of SVC. SVC is desired to be placed at the bus whose voltage has drastically fallen, which can be termed as the weakest bus in the system.

The weakest bus in the system is identified by the continuation power flow analysis using PSAT. We identify the weakest buses to be 4, 5, 9. The figure 6 shows the P-V curve for the weakest three bus voltages.

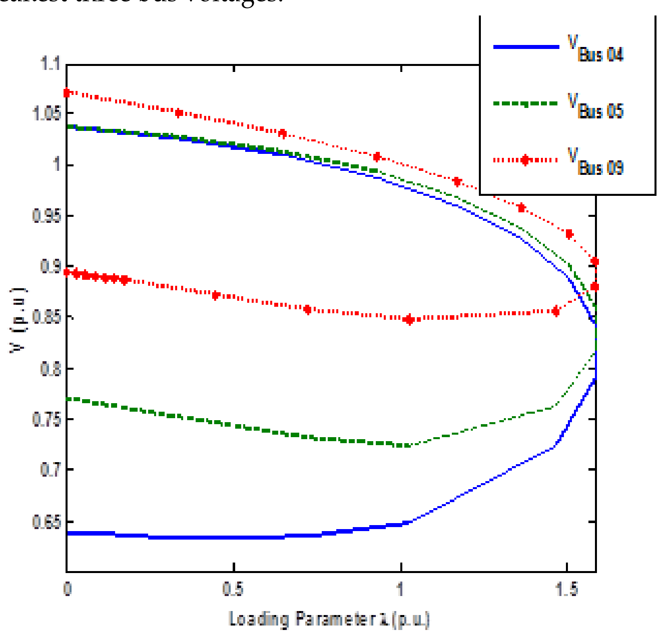

Fig 6: Nose curve of bus 4, 5 and 9.

Among these buses bus 9 has the weakest voltage profile.

Thus the best location of SVC is at bus9.The SVC parameters used in this case is, $X_L = 0.7$ and $X_C = 0.35$ with the firing angle of 2.979 radians. It is expected that by placing SVC at this location there is a marginal increase in the bus voltages. The voltage profile for the system with SVC at bus 9 is shown in figure 7.

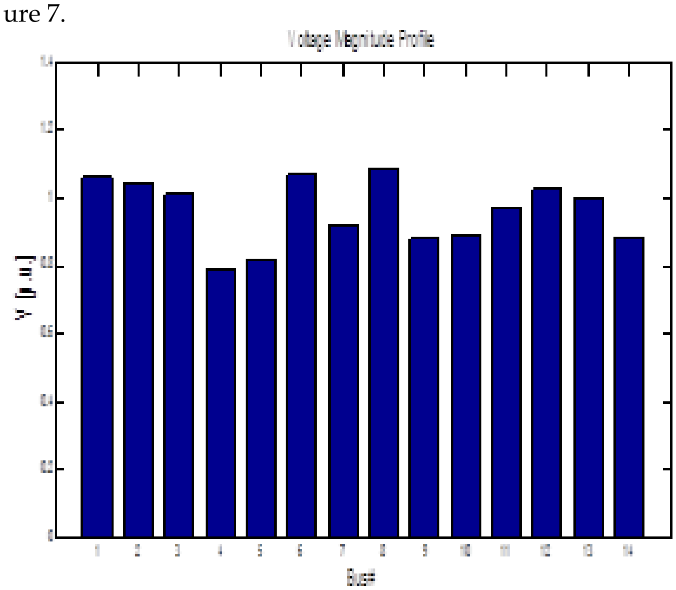

Fig 7: voltage magnitude with SVC.

The following figure 11 similarly shows the improvement of voltage at the weakest buses namely bus 4, 5 and 9 using SVC in the 14 bus system.

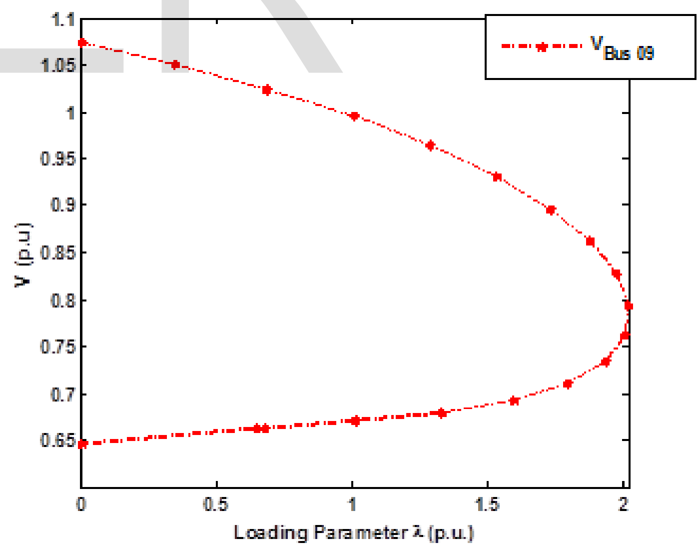

Fig 8: Nose curve of bus 9 with SVC.

We find the significant difference in the voltage profile at various locations in the above test systems before and after the placement of SVC indicating that it is effective in requirement to improve voltage profile of an interconnected power system in case of an occurrence of large disturbance in the form of a 3 phase fault.

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Table1: Voltage profile of IEEE 14 bus system with base case, with fault and with SVC at bus 9 in the system.

Bus no	Voltage (Base condition)	Voltage (Faulted condition)	Voltage (With SVC)
1	1.06	1.06	1.06
2	1.045	1.045	1.045
3	1.01	1.01	1.01
4	0.99772	0.67802	0.84387
5	1.0024	0.72242	0.94127
5	1.07	1.07	1.07
7	1.0347	0.80401	0.93386
8	1.09	1.09	1.09
9	1.0111	0.66421	0.88387
10	1.0105	0.7506	0.89278
11	1.0346	0.89264	0.96056
12	1.0461	0.98627	1.0169
13	1.0362	0.94214	0.99906
14	0.99568	0.72689	0.88418

The graphical representation of the above table containing the voltage magnitude for different cases is shown in the figure 9.

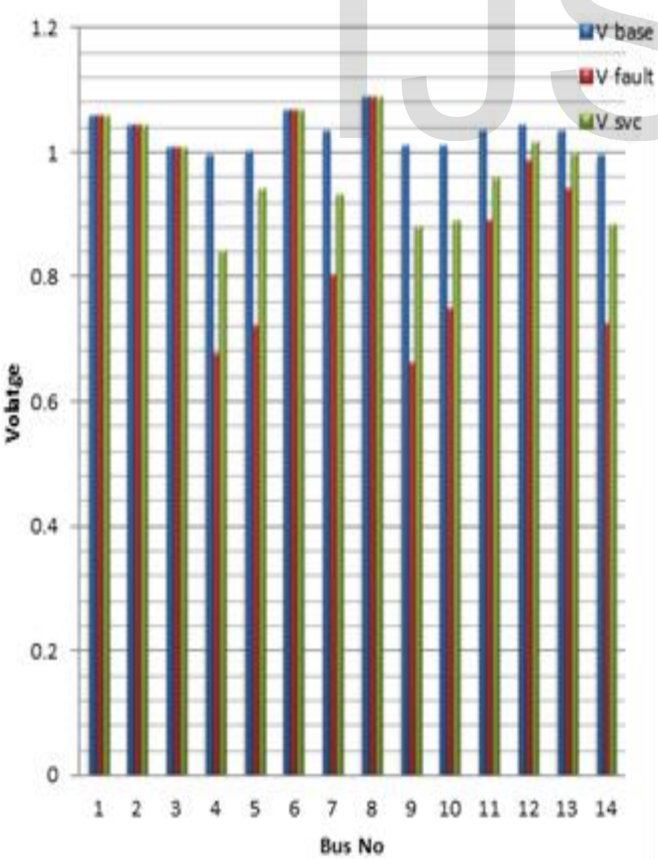

Fig 9: Voltage magnitude profile.

We observe that there is a significant difference in the voltage profile at various buses in the above test systems before and after the placement of FACTS devices indicating that the SVC is effective when it is required to improve voltage profile of an interconnected power system in case of an occurrence of large disturbance in the form of a 3 phase fault. Thus there is an overall enhancement in the voltage stability of the system.

6 Conclusion

FACTS device Static VAR compensator (SVC) is used for voltage stability enhancement. The test system which is the IEEE 14 bus system is studied and simulated using the continuation power flow analysis. The simulation results show a significant increase in the voltage profile at different buses by the placement of FACTS. This can be clearly observed from the nose curves and the voltage magnitude profiles. Thus FACTS are powerful devices that aid in the improvement of voltage. It also increases the system security and reliability therefore contributing in solving many power system problems.

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