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Voltage Stability Improvement by using Static Var Compensator

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Abstract— This paper implemented the improvement of voltage stability by using Flexible Alternating Current Transmission System (FACTS) device. The main objective of this paper is to improve voltage stability based on static criteria. The methods of continuation power flow are proposed in case of the increasing load on the system. The proposed method is based on Static Var Compensator (SVC) injection to increase the steady state voltage stability and power capability of the system. The IEEE-9 bus system is simulated to test the increasing loadability of a power system. It is to develop a simple, fast and convenient procedure which can effectively use to enhance the voltage stability. The propose work has been simulated by using Power System Computer Aided Design and Power World Simulator software.

Keywords— IEEE 9 Bus System; SVC; PSCAD; PWS

I. INTRODUCTION

Modern power system is heavily stressed due to increasing demand. So the modern power system is facing challenges. The existing transmission line is not capable of supporting this huge power demand. One of the major problems for this is voltage instability. Voltage stability is a major concern in power system operation. So, it is important to know the maximum permissible loading to operate the system in stable state. Voltage stability is to maintain acceptable voltages level in the power system under subjected to normal conditions, abnormal conditions and after being increase in load. The reasons for voltage instability are increase in load demand, change in system condition and decrease in voltage. Voltage instability occurs in heavily loaded power system. The voltage stability analysis determines whether a given system is voltage secure or not. So, it is important for a system to know its stability limit [1].

The FACTS devices provide a high potential for power system stability enhancement apart from steady-state flow control. FACTS technology are emerging new devices emanating from latest innovative technologies that are capable of altering impedance, phase angle and/or voltage at particular points in power systems. Among all the FACTS controllers, SVC is a fast acting dynamic reactive compensation for voltage support during loading events which would otherwise decrease the voltage for a significant length of time. SVC also dampens the power swings and reduces system losses to optimized reactive power control. Power System Computer Aided Design (PSCAD) [2] and Power World Simulator (PWS) [3] has been used in this paper to conduct simulations on voltage regulation and load flow capability at the point of connection of SVC to the system. The dissertation deals with the simulation of SVC on PSCAD and PWS along with the associated details of the circuit design.

II. FACTS DEVICE

Now today's increase in population the power demand goes on increasing and as a result we have to increased generation according to need of demand by installing new power plants and erecting new transmission lines. Moreover as there is deregulation in the electricity market we have to load the lines up to its upper thermal limit. This loading of lines up to its thermal limit was possible with the FACTS devices. A FACTS is a system composed of static equipment used for the AC transmission of electrical energy. It means to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system. In this paper a SVC is used to improve the voltage stability of the IEEE 9 bus system. SVC is a shunt connected Static VAR Generator or Absorber whose output is adjusted to exchange capacitive or inductive current to maintain or control specific parameters of the electrical power system. It helps in voltage regulation, reactive power control and improving the transient stability of the system. SVC is a first device that can control bus voltage thereby improving the voltage profile of the system.

An SVC comprises one or more fixed or switched shunt capacitors or reactors, of which at least one bank is switched by thyristors. Elements which may be used to make an SVC typically include [4]:

1. Thyristor controlled reactor (TCR)
2. Thyristor switched capacitor (TSC)
3. Harmonic filters
4. Mechanically switched capacitors or reactors

Basically SVC classified into two types are as

1. Fixed controlled thyristor controlled reactor (FC-TCR)

2. Thyristor switched capacitor- thyristor controlled reactor (TSC-TCR)

In this paper FC-TCR type SVC is used to get system remain in a stable condition after being subjected to over loading of the system. Fig. 1 shows that the FC-TCR are connected on the secondary side of a coupling transformer. The capacitive reactive power at fundamental frequency has provided by tuned and high pass filters connected in parallel. The voltage signal is taken from the high voltage SVC bus using a potential transformer. The voltage across valve is minimum and positive when the TSC is switched in using two thyristor switches at the instant in a cycle. This results in minimum switching transients. In steady state, TSC does not generate any harmonics. For switching off a TSC, the gate pulses are blocked and the turns off thyristors when the current through them fall below the holding currents.

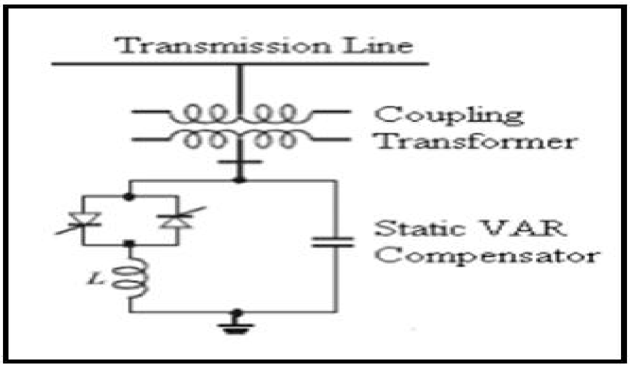

Fig. 1. Schematic Diagram of FC-TCR

The control concept of svc is based on controlling of shunt susceptance (B) which can be controlled by changing the firing angle of thyristor. The control objective of the SVC is to maintain a desired voltage at the high-voltage bus. The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive). The variation of reactive power is performed by switching three-phase capacitor banks and inductor banks connected on the secondary side of a coupling transformer. Each capacitor bank is switched on and off by three thyristor switches (Thyristor Switched Capacitor or TSC). Reactors are either switched on-off (Thyristor Switched Reactor or TSR) or phase-controlled (Thyristor Controlled Reactor or TCR). SVC is a combination of controllable shunt reactor and a shunt capacitor. The controlled shunt reactor is series combination of reactor and ant parallel connected pair of thyristor which is known as TCR. The susceptance of SVC can be varied by varying the firing angle of thyristor (TCR branch) in the range of 900-1800. During normal operation, SVC can control total susceptance according to the terminal voltage. At minimum and maximum susceptance, SVC behaves like a fixed capacitor or inductor. When system voltage dips due to any fault, SVC immediately provides reactive power to the system to improve the voltage.

Total Succeptance is B [5][6]

$$B = B_L + B_C$$

Where B_L = Inductive Succeptance

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$$B_L = \frac{-1}{X_L}\left(1 - \frac{2\alpha}{\pi} - \frac{\sin 2\alpha}{\pi}\right)$$

And B_C = Capacitive succeptance

$$B_C = \frac{1}{X_C}$$

The reactive power inject at 5th bus is

$$Qsvc = -(V^2)\,B$$

Where V is the voltage of the line.

III. SYSTEM UNDER STUDY

IEEE 9 bus system contains 6 transmission line of 1 m length each which are interconnected to buses as shown in Fig. 2 Fundamental system frequency is 60 Hz and base voltage is 230 kV .Three generators of base 77, 163 and 86 MVA are connected to bus 1, bus2 and bus 3 respectively [7][8]. Whereas, loads are connected at bus no 5, 6 and 8. System frequency is 60 Hz. Different loading has done on bus no. 5 of weakest bus [9][10]. Moreover the sampling time taken for the analysis is 0.1 second, which relates to a sampling frequency 4 KHz.

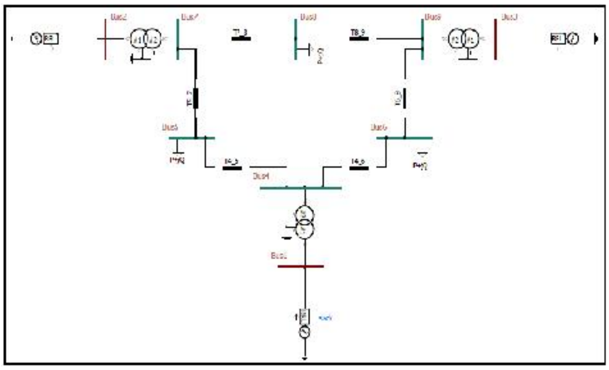

Fig. 2. Single Line Diagram of IEEE 9 Bus System [11]

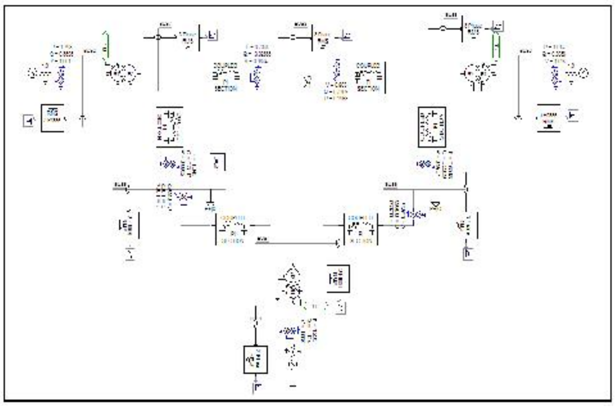

Fig. 3. Simulated Circuit of IEEE 9 BUS SYSTEM in PSCAD [12]

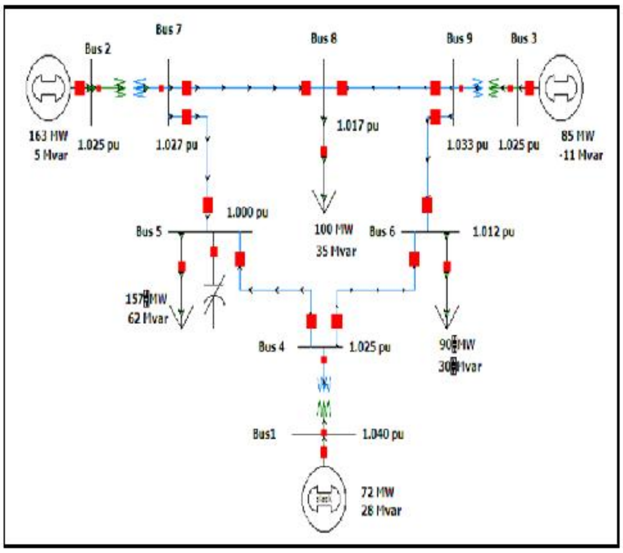

Fig. 4. Simulated Circuit of IEEE 9 BUS SYSTEM in PWS [3]

IV. RESULTS AND DISCUSSION

The voltage signal are used in this paper and it is monitored for different loading conditions. The loading conditions are as

TABLE I. LOADING CONDITION

% Loading	*Load on 5th Bus*		*Load on 6th bus*		*Load on 8th bus*	
	P (MW)	*Q (MVAr)*	*P (MW)*	*Q (MVAr)*	*P (MW)*	*Q (MVAr)*
100	125	50	90	30	100	35
105	131.25	52.5	90	30	100	35
110	137.5	55	90	30	100	35

So from above table it is clear that the loading has to be done on load bus 5 this is to be selecting as weak bus as the voltage of that bus is less compare to remaining bus at 100% loading condition. To understand the need of voltage stability, the voltage profile of all the buses are checked without and with SVC in the IEEE 9 bus system at 110 % loading on the system. Variation of bus Voltage (pu) with time (sec) in PSCAD as shown in Fig. 5 and Fig.6

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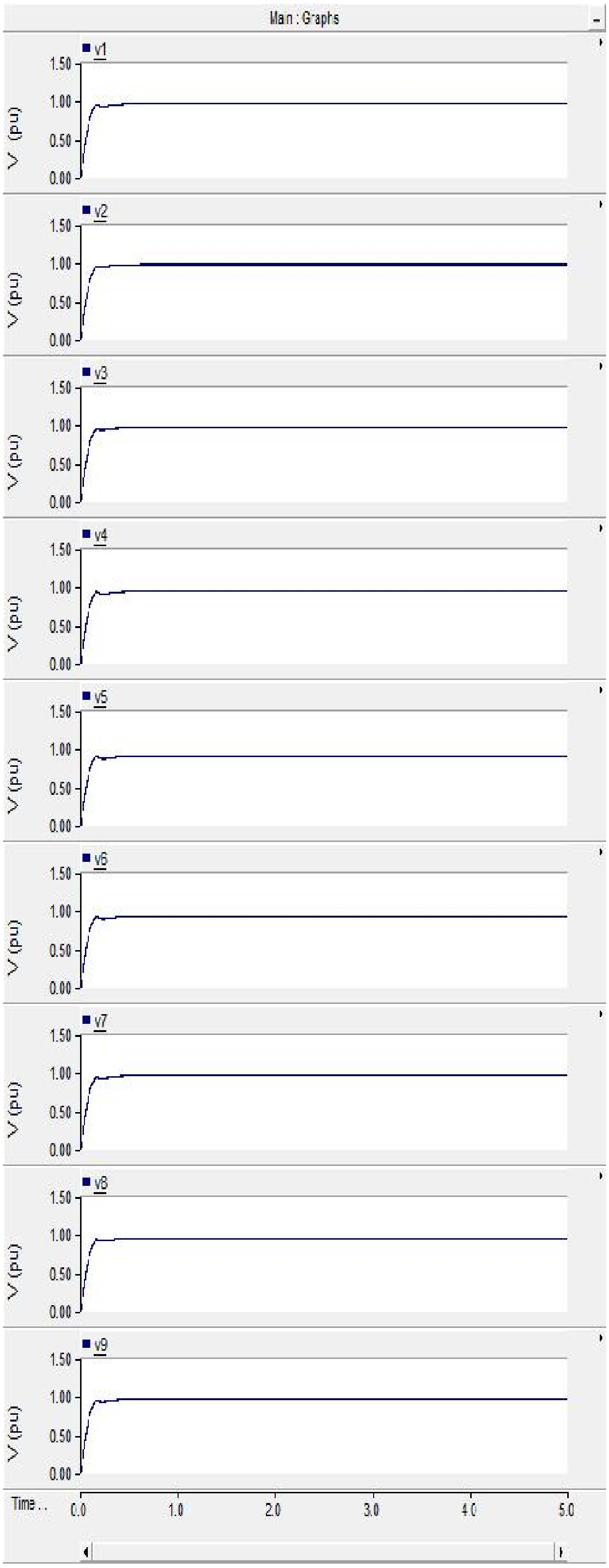

Fig. 5. Voltage waveform of each bus at 110% loading without SVC

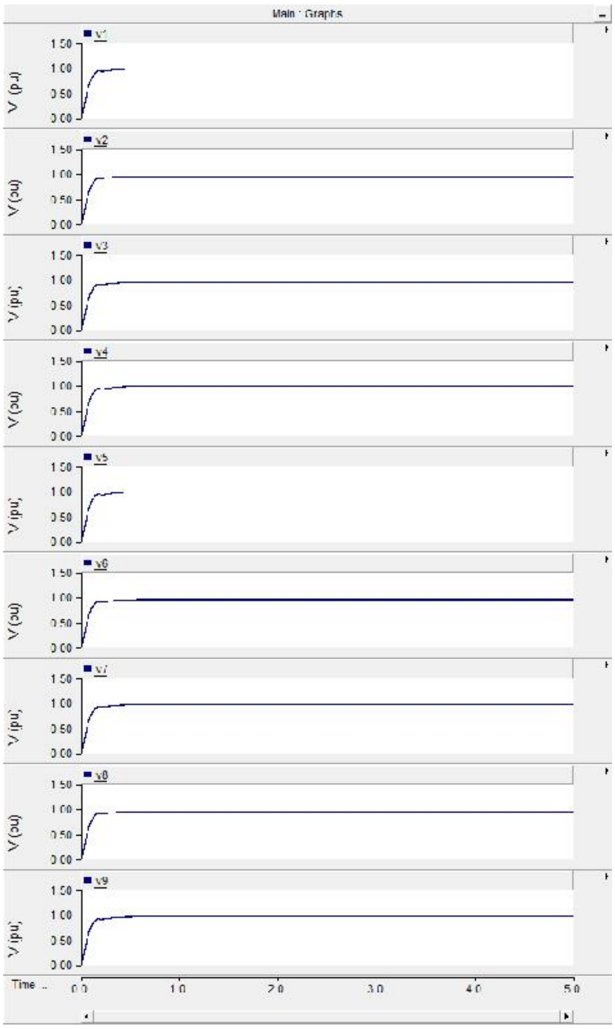

Fig. 6. Voltage waveform of each bus at 110% loading with SVC

TABLE II. VOLTAGE READING OF EACH BUS OF DIFFERENT LOAD CONDITION ON 5TH BUS WITHOUT SVC

load in %	*voltage reading of each bus in PU*								
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
100	1.03	1	1.02	1.02	0.99	1	1.01	1	1.02
105	1.03	1	1.02	1.01	0.98	1	1	1	1.02
110	1.03	0.99	1.02	1	0.96	0.99	1	0.99	1.02

From table 2 it is clear that at different loading condition at bus no.5 the voltage drops down according to incresed in load without SVC. But after injecting SVC device the voltage level is improved.

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TABLE III. VOLTAGE READING OF EACH BUS OF DIFFERENT LOAD CONDITION ON 5TH BUS WITH SVC

load in %	***voltage reading of each bus in PU***								
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***
100	1.03	1	1.02	1.02	1.00	1	1.01	1	1.02
105	1.03	1	1.02	1.02	0.99	1	1.01	1	1.02
110	1.03	1	1.02	1.02	0.99	1	1.01	1	1.02

From table 3 it shows that after incorporating SVC device the voltage profile at bus no.5 for 110 % loading is improved from 0.96 pu to 0.99 pu

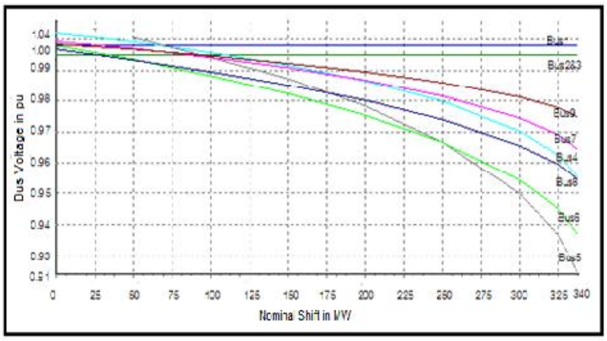

Fig. 7. The PV curve for 110% loading without SVC device in PWS

Fig. 7 shows the variation of bus voltage (in pu) with power flow (in MW) without connecting SVC. For a case of 110% loading, the active power flow is 327.5 MW and voltage at bus no.5 is 0.96 pu.

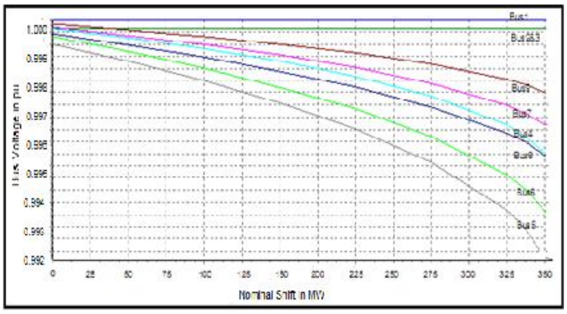

Fig. 8. The PV curve for 110% loading with SVC device in PWS

Fig. 8 shows the variation of bus voltage (in pu) with power flow (in MW) with connecting SVC at bus no.5. For a case of 110% loading, with connecting SVC the active power flow becomes 338 MW and bus voltage becomes 0.992 pu.

TABLE IV. ACTIVE AND REACTIVE POWER RESULTS WITH AND WITHOUT SVC

% Loading	***Load at bus no.5 without SVC***		***Voltage(pu) at bus no.5 without SVC***	***Load at bus no.5 with SVC***		***Voltage (pu) at bus no. 5 With SVC***
	P (MW)	***Q (MVAr)***		***P (MW)***	***Q (MVAr)***	
100	125	50	0.99	136	56	0.99
105	131.25	52.5	0.98	142	58	0.992
110	137.5	55	0.96	148	61	0.992

V. CONCLUSION

In this study, the effectiveness of shunt FACTS devices such as SVC has been studied in improving the voltage stability of IEEE 9 bus system with different load conditions. The simulation results shown here shows the effective working of SVC. It has been observed that the voltage profile of bus number 5 is found to be 0.96 pu without svc under 110% loading condition and with SVC it improves to 0.992 pu. At the same loading condition the loadability of system increases by 10.5 MW which is observed in P-V curve obtained using power world simulator. SVC can effectively control voltage and reactive power in system.

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