Power Quality Enhancement by Static Var Compensator in Transmission System

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Abstract— The role of the transmission network in the Power System is to transmit the power generated in the power plants to the load centers and the interconnected power systems. The transmission of electric power has to take place in the most efficient way in addition to providing flexibility in the process. Hence Flexible A.C. Transmission System (FACTS) devices are used. A Static VAR Compensator (SVC) is a shunt-connected FACTS controller that is able to exchange reactive power with the power system in a controlled way of static controllers to enhance the controllability and increase the power transfer capability. In this paper the operation of shunt SVC in the 5 bus system with different loading conditions are studied. Dynamic VAR compensation and voltage control at all the buses are analyzed with and without SVC. Losses of transmission lines with and without SVC are compared. Simulation is carried by using Mi-Power software Simulation package.

Key words: Flexible AC Transmission System, Static VAR Compensator, Mi-Power

I. INTRODUCTION

Today's power system is highly complex and requires careful design of new devices taking into consideration of already existing equipments. Now-a day, number of private generating units is getting commissioned due to power generation policy and open access to transfer power. But, due to variety of environmental and regulatory concern, the expansion of electric power transmission facilities is restricted. Power Transmission and Generation utility would be benefited if they could increase line power capability. It is well known that the power flow through transmission line is a function of line impedance, magnitude and phase angle of bus voltage. If these parameters can be controlled, the power flow through the transmission line can be controlled in a predetermined manner. Controlling power flow in modern power systems can be made more flexible by the use of recent developments in power electronics and computing control technology. The Static VAR Compensator (SVC) is a Flexible AC transmission system (FACTS) device that can regulate voltage, power factor, harmonics and stabilizing the system. The objective of the project is to achieve significant improvements in operating parameters of power systems such as voltage profile, control of real and reactive power, and reduction in transmission line losses by connecting SVC in 5 bus system considered for study. Finally the simulation results have been presented to indicate the improvement in the performance of the SVC to control voltage, active and reactive power in transmission system.

II. STATIC VAR COMPENSATOR

SVC is a shunt connected variable impedance type FACTS device where the current through a reactor is controlled using back to back connected thyristor valves. The Static VAR Compensator is used to control the bus voltage. It controls the bus voltage profile by injecting and drawing the reactive power from the system. The basic circuit of SVC is shown in Figure 1. It contains a fixed capacitor and variable inductor connected in parallel. By varying the inductive reactance the current drawn or injected by the SVC is controlled.

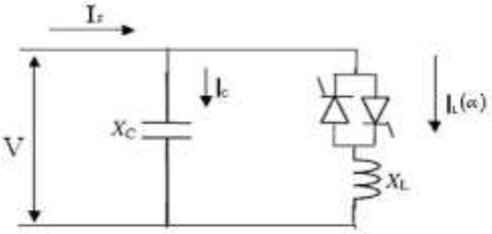

Fig 1: Basic circuit of SVC

III. V-I CHARACTERISTICS OF SVC

SVC is basically a shunt connected static VAR generator/load whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific power system variables: typically, the controlled variable is the SVC bus voltage. One of the major reasons for installing a SVC is to improve dynamic voltage control and thus increase system load ability. The SVC can be operated in two different modes: • In voltage regulation mode

– In VAR control mode (the SVC susceptance is kept constant).

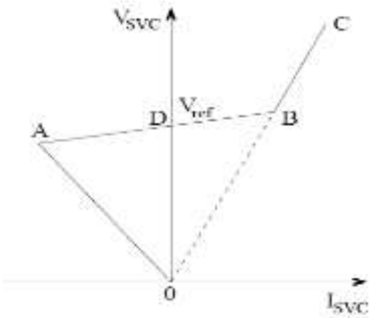

Fig 2 : V-I Characteristics of SVC

IV. MODEL OF THE 5 BUS SYSTEM

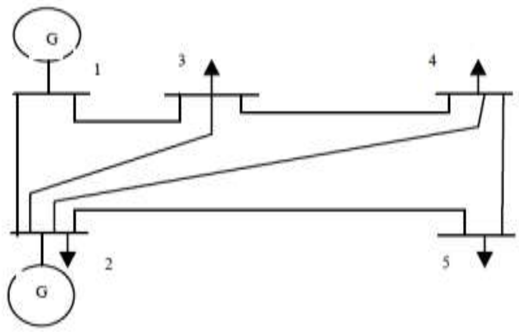

Fig 3: A Standard 5-Bus Network

A 5-Bus test system as shown in Figure is used. The test system consists of two generators, seven transmission lines, and four loads. Per-unit transmission line series impedances and shunt susceptances are given on 100 MVA base in table. Real power generation, real and reactive power loads in MW and MVAR are given in table. Assume the base voltage for the bus as 220 kV and system frequency as 50 Hz. Bus 1 is considered as slack bus. Load flow analysis is done using Newton-Raphson method with a tolerance value of 0.001

BUS NO	BUS VOLTAGE(p.u)	GENERATION (MW)	GENERATION (MVAR)	LOAD (MW)	LOAD (MVAR)
1	1.06	0	0	0	0
2	1.0	40	30	20	10
3	1.0	0	0	45	15
4	1.0	0	0	40	5
5	1.0	0	0	60	10

V. SIMULATION MODEL OF THE SYSTEM

A. *Case 1: Normalcase*

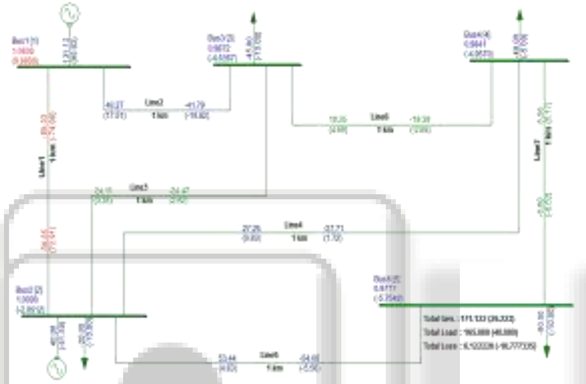

Fig 4.1: 5 bus model without SVC

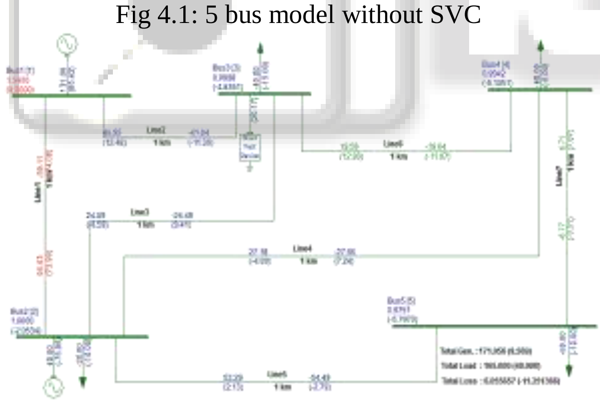

Fig 4.2: 5 bus model with SVC

B. *Case 2: Overloading Case*

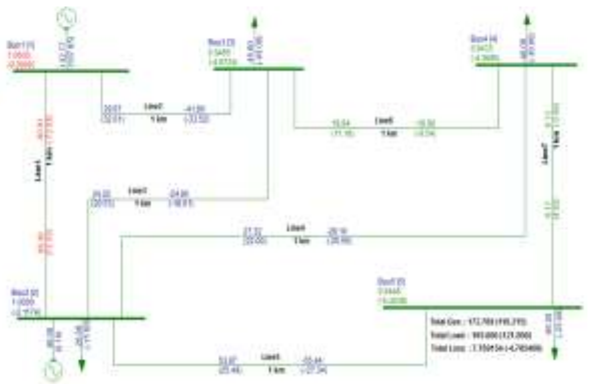

Fig 4.3: 5 bus model without SVC

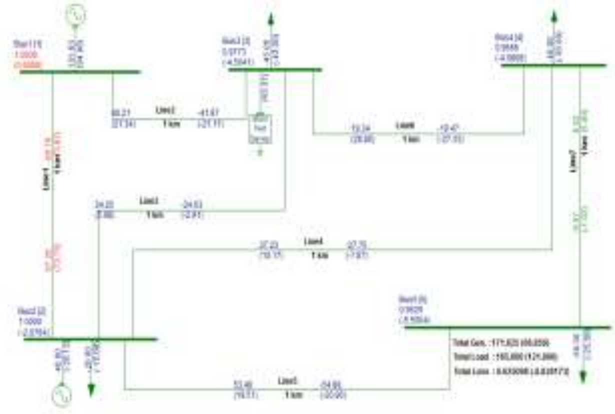

Fig 4.4: 5 bus model with SVC

C. *Case 3: Underloading Case*

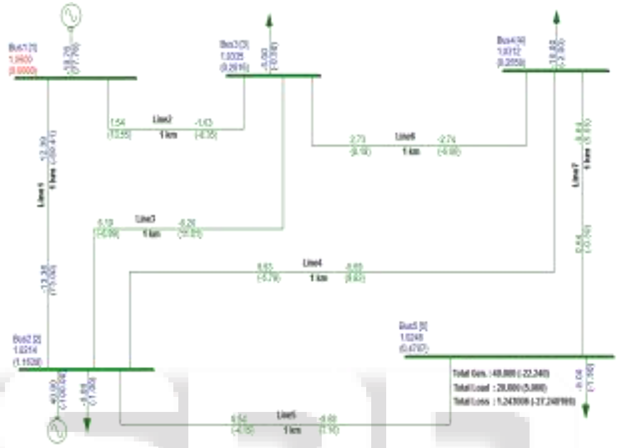

Fig 4.5: 5 bus model without SVC

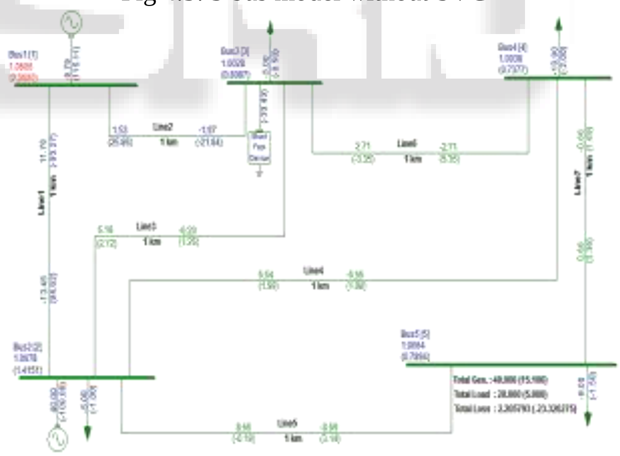

Fig 4.6: 5 bus model with SVC

VI. SIMULATION RESULTS

A. *Case 1: Normal Case*

BUS NO	WITHOUT SVC VOLTAGE (p.u)	WITHOUT SVC ANGLE (DEGREE)	WITH SVC VOLTAGE (p.u)	WITH SVC ANGLE (DEGREE)
1	1.0600	0	1.0600	0
2	1.0000	-2.06	1.0000	-2.05
3	0.9872	-4.64	0.9998	-4.84
4	0.9841	-4.96	0.9942	-5.11
5	0.9717	-5.76	0.9751	-5.80

Table 5.1: Voltage Profile

			WITHOUT SVC		WITH SVC	
LINE NO	FROM BUS	TO BUS	REAL POWER LOSS (MW)	REACTIVE POWER LOSS(MVAR)	REAL POWER LOSS (MW)	REACTIVE POWER LOSS(MVAR)
1	1	2	2.4859	1.0868	2.4807	1.0712
2	1	3	1.5178	-0.6922	1.3955	-1.1215
3	2	3	0.3595	-2.8708	0.3927	-2.8212
4	2	4	0.4609	-2.5545	0.4755	-2.5506
5	2	5	1.2150	0.7287	1.1948	0.6580
6	3	4	0.0401	-1.8230	0.0532	-1.8286
7	4	5	0.0431	-4.6525	0.0633	-4.6587
TOTAL LOSS			6.1223	-10.7775	6.0557	-11.2514

Table 5.2: TOTAL LINE LOSSES

	WITHOUT SVC	WITH SVC
TOTAL REAL POWER GENERATION (MW)	171.122	171.056
TOTAL REACTIVE POWER GENERATION (MVAR)	29.223	8.569
GENERATION POWER FACTOR	0.986	0.999
TOTAL SHUNT FACTS INJECTION (MVAR)	0	20.175
TOTAL REAL POWER LOAD (MW)	165	165
TOTAL REACTIVE POWER LOAD (MVAR)	40	40
LOAD POWER FACTOR	0.972	0.972
TOTAL REAL POWER LOSS (MW)	6.1223	6.0557
PERCENTAGE REAL LOSS	3.578	3.540
TOTAL REACTIVE POWER LOSS (MVAR)	-10.7775	-11.2514

Table 5.3: SUMMARY OF RESULTS

B. *Case 2: Overloading Case*

	WITHOUT SVC		WITH SVC	
BUS NO	VOLTAGE (p.u)	ANGLE (DEGREE)	VOLTAGE (p.u)	ANGLE (DEGREE)
1	1.0600	0	1.0600	0
2	1.0000	-2.12	1.0000	-2.08
3	0.9486	-4.07	0.9773	-4.5
4	0.9433	-4.37	0.9666	-4.69
5	0.9448	-5.45	0.9529	-5.50

Table 5.4: VOLTAGE PROFILE

			WITHOUT SVC		WITH SVC	
LINE NO	FROM BUS	TO BUS	REAL POWER LOSS (MW)	REACTIVE POWER LOSS(MVAR)	REAL POWER LOSS (MW)	REACTIVE POWER LOSS(MVAR)
1	1	2	2.5237	1.2004	2.4960	1.1172
2	1	3	2.1873	1.5034	1.6554	-0.2305
3	2	3	0.6252	-1.9239	0.3785	-2.7746
4	2	4	0.7791	-1.4424	0.5203	-2.3077
5	2	5	1.5618	1.8464	1.4048	1.3524
6	3	4	0.0518	-1.6341	0.1235	-1.5190
7	4	5	0.0403	-4.3353	0.0466	-4.4660
TOTAL LOSS			7.7692	-4.7855	6.6251	-8.8282

Table 5.5: TOTAL LINE LOSSES

	WITHOUT SVC	WITH SVC
TOTAL REAL POWER GENERATION (MW)	172.769	171.625
TOTAL REACTIVE POWER GENERATION (MVAR)	116.215	68.859
GENERATION POWER FACTOR	0.830	0.92
TOTAL SHUNT FACTS INJECTION (MVAR)	0	43.313
TOTAL REAL POWER LOAD (MW)	165	165
TOTAL REACTIVE POWER LOAD (MVAR)	121	121
LOAD POWER FACTOR	0.806	0.806
TOTAL REAL POWER LOSS (MW)	7.7692	6.6251
PERCENTAGE REAL LOSS	4.497	3.860
TOTAL REACTIVE POWER LOSS (MVAR)	-4.7855	-8.8282

Table 5.6: SUMMARY OF RESULTS

C. *Case 3: Underloading Case*

	WITHOUT SVC		WITH SVC	
BUS NO	VOLTAGE (p.u)	ANGLE (DEGREE)	VOLTAGE (p.u)	ANGLE (DEGREE)
1	1.0600	0	1.06	0
2	1.0213	1.16	1.0078	1.42
3	1.0335	0.26	1.0028	0.81
4	1.0312	0.26	1.0038	0.74
5	1.0246	0.47	1.0064	0.79

Table 5.7: VOLTAGE PROFILE

			WITHOUT SVC		WITH SVC	
LINE NO	FROM BUS	TO BUS	REAL POWER LOSS (MW)	REACTIVE POWER LOSS(MVAR)	REAL POWER LOSS (MW)	REACTIVE POWER LOSS(MVAR)
1	1	2	0.9703	-3.5894	1.6869	-1.3574
2	1	3	0.0905	-5.2079	0.4354	-4.0170
3	2	3	0.0683	-4.0177	0.0231	-3.9735
4	2	4	0.0602	-4.0323	0.0262	-3.9681
5	2	5	0.0409	-3.0166	0.0308	-2.9504
6	3	4	0.0055	-2.1151	0.0026	-2.0055
7	4	5	0.0073	-5.2611	0.0009	-5.0484
TOTAL LOSS			1.243	-27.2401	2.2059	-23.3203

Table 5.8: TOTAL LINE LOSSES

	WITHOUT SVC	WITH SVC
TOTAL REAL POWER GENERATION (MW)	40	40
TOTAL REACTIVE POWER GENERATION (MVAR)	-22.240	15.106
GENERATION POWER FACTOR	0.874	0.936
TOTAL SHUNT FACTS DRAWAL (MVAR)	0	33.428
TOTAL REAL POWER LOAD (MW)	28	28
TOTAL REACTIVE POWER DRAWAL (MVAR)	10.757	9.794
TOTAL REACTIVE POWER LOAD (MVAR)	5	5
LOAD POWER FACTOR	0.984	0.984
TOTAL REAL POWER LOSS (MW)	1.243	2.2059
PERCENTAGE REAL LOSS	3.108	5.514
TOTAL REACTIVE POWER LOSS (MVAR)	-27.2401	-23.3203

Table 5.9: SUMMARY OF RESULTS

VII. CONCLUSION

This paper deals with the application of the SVC. The detailed model of the SVC were implemented and tested in Mi-Power software simulation package environment. The effect of SVC installed in power transmission system path are analyzed in this paper, and following conclusions were drawn.

Capacitive reactive power injected by SVC during overloading conditions is 43 MVAR and consumes Inductive reactive power of 33 MVAR during lightly loading condition to maintain voltage across the buses near to 1 p.u. Line losses has been reduced in normal case and overloading case with the presence of SVC, but losses has been increased during lightly loaded condition. Reactive power generation by conventional generation has been reduced with the presence of SVC. This increases the stability of the generators.

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