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SVC and STATCOM as a Voltage stability Improvement

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Abstract- *The study of shunt connected FACTS devices is a connected field with the problem of reactive power compensation and better mitigation of transmission related problems in today's world. In this paper we study the shunt operation of FACTS controller, the STATCOM, and how it helps in the better utilization of a network operating under normal conditions. First we carry out a literature review of many papers related to FACTS and STATCOM, along with reactive power control. With the effect of restrictions on building new linesandgrowing demand, Transmission networks of modern power systems are becoming more stressed. One of the solutions of such a stressed system is the Flexible actransmission system (FACTS) devices.From the family of flexible AC transmission systems (FACTS), the static synchronous compensator (STATCOM) is a shunt device of this family.By the controlling an amount of reactivepower absorbed from or injected into power system, the STATCOM regulates its terminal voltage.STATCOM absorbs reactive power,when the voltage of system is high and it generates reactive power,when the voltage of system is low.In this paper,performance of SVC and STATCOM is done. The simulation result proves the effectiveness of these devices in improving Voltage stability.*

Keywords: *STATCOM, Transmission, Static, VAR*

I. INTRODUCTION

With deregulation of electricity markets worldwide, there are good number of market players trying to engage in power buying and selling business. The sudden increase in peak demand and power transfer affects voltage security. In some of the incidents, voltage collapse was responsible for the outage. One of the major reasons for voltage instability is reactive power imbalance in the system [1]. This directly affects the load ability of a bus in a power network. In order to prevent a voltage collapse when system approaches load ability limit, a local reactive power support can immediately provide relief and enhance static voltage stability. With increased power flow, there is corresponding decrease in voltage at the bus. Further increase in loading leads to shortage of reactive power. Thereafter, any further increase in active power transfer causes a quick decrease in magnitude of voltage of the bus. As the critical point is reached, heavy reactive power losses lead to a high voltage drop and there voltage collapse takes place. To prevent the system, reaching this state is to augment reactive power support or cut-off reactive power demand [2]. This phenomenon sometimes leads to major black-out [3]. One of the methods to overcome this problem is to place reactive power support on the weakest bus 9 bus having lowest margin or near the collapse point). FACTs devices- SVC and STATCOM can provide reactive power support. The effect of SVC and TCSC on voltage collapse has been studied by Canizares and Faur[4]. A. Kazemi et al studied the voltage stability using STATCOM and UPFC controllers [5].Shunt connected static var compensators (SVCs) are used extensively to control the AC voltage in transmission networks. Power electronic equipment, such as the thyristor controlled reactor (TCR) and the thyristor switched capacitor (TSC) have gained a significant market, primarily because of well-proven robustness to supply dynamic reactive power with fast response time and with low maintenance. With the advent of high power gate turn-off thyristors and transistor devices (GTO, IGBT, …) a new generation of power electronic equipment, STATCOM, shows great promise for application in power systems [6,7]. This paper aims to explain the benefits of SVCs and STATCOMs for application in utility power systems. Installation of a large number of SVCs and experience gained from recent STATCOM projects throughout the world motivates us to clarify certain aspects of these devices. The performance of the STATCOM is compared with that ofconventional static var compensator, SVC.

II. STATIC VAR COMPENSATOR (SVC)

A SVC (Static Var Compensator) is a high voltage system that controls dynamically the network voltage at its coupling point. Its main task is to keep the network voltage constantly at a set reference value.Electrical loads both generate and absorb reactive power. Since the transmitted load varies considerably from one hour to another, the reactive power balance in a grid varies as well. The result can be unacceptable voltage amplitude variations, a voltage depression, or even a voltage collapse. A rapidly operating Static Var Compensator (SVC) can continuously provide the reactive power required to control dynamic voltage swings under various system conditions and thereby improve the power system transmission and distribution performance. Installing an SVC at one or more suitable points in the network can increase transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions. In addition, an SVC can mitigate active power oscillations through voltage amplitude modulation.If the load of the power system is leading, the SVC consumes VAR from the system by using thyristors controlled reactors. Under lagging conditions, the capacitor banks are automatically switched in, thus providing a higher system voltage. By connecting the thyristors controlled reactor, which is continuously variable, along with a capacitor bank step, the net result is continuously variable leading or lagging power. In industrial applications, SVCs are placed near to high and rapidly varying loads such as arc furnaces [8] [9].

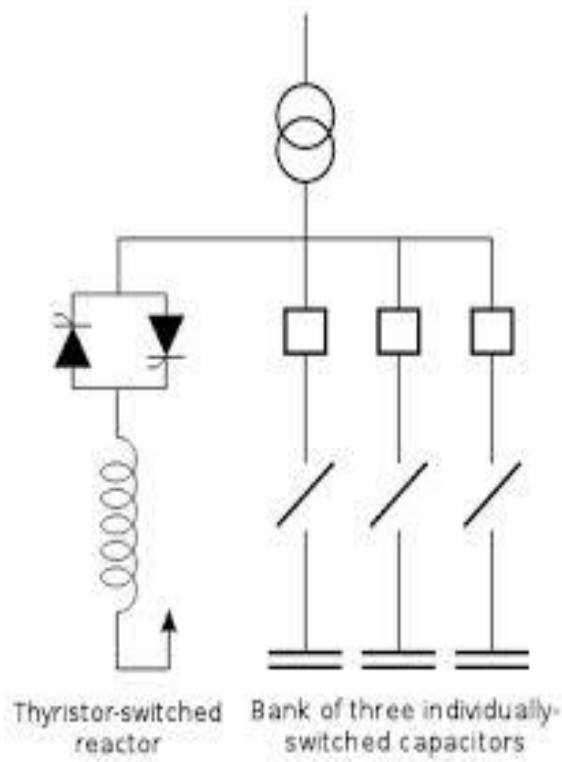

Fig. 1: Model of SVC

III. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

Static synchronous compensators (STATCOMs) are part of the flexible alternating current transmission systems (FACTS) device family. Their primary purpose is to supply a fast-acting, precise, and adjustable amount of reactive power to the ac power system to which they are connected. STATCOMs achieve this by adjusting the magnitude and polarity (phase) of the reactive component of the current flowing through their ac side. This enables STATCOMs to control the amount and direction of flow of the reactive power exchanged with the ac power system. STATCOMs can be used for voltage compensation at the receiver end of ac transmission lines, thus replacing banks of shunt capacitors. When used for this purpose, STATCOMs offer a number of advantages over banks of shunt capacitors, such as much tighter control of the voltage compensation at the receiver end of the ac transmission line and increased line stability during load variations. STATCOMs are also commonly used for dynamic power factor correction (i.e., dynamic reactive power compensation) in industrial plants operating with large random peaks of reactive power demand. STATCOMs increase the power factor of the plant, minimize the voltage fluctuations at the plant input (which prevents damage to the equipment), and reduce the plant's operating costs. This course, Static Synchronous Compensators (STATCOMs), teaches the basic concepts of voltage compensation in ac transmission lines and power factor correction in large industrial plants using STATCOMs. Students are introduced to the operation of STATCOMs, and their different components. They also learn how a STATCOM achieves automatic voltage control and automatic reactive power control. Finally, the theory presented in the manual is verified by performing circuit.

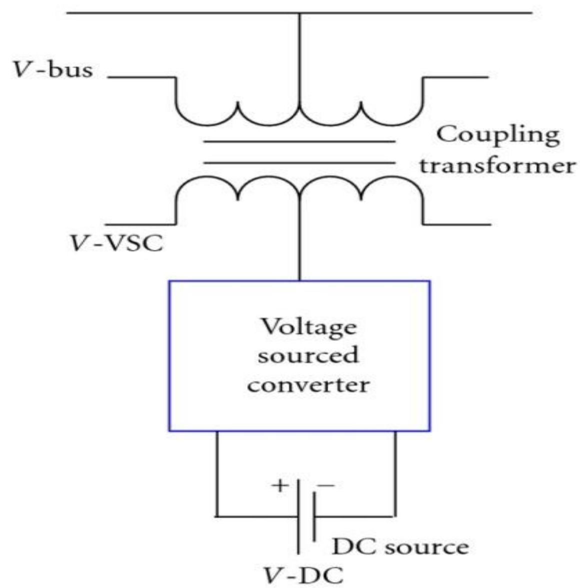

Fig. 2: Model of STATCOM

IV. SIMULINK MODEL AND RESULT

The model of the Simulink is shown in figure. It consists of two power grids of rating 2600 MVA and 2300 MVA. These grids are connected through a transmission line of 500 km line of rating 500 kV. When the STATCOM is not in operation, the natural power flow is of 930 MW from bus B1 to B3. The fig. 4 shows the graph between the SVC and STATCOM.

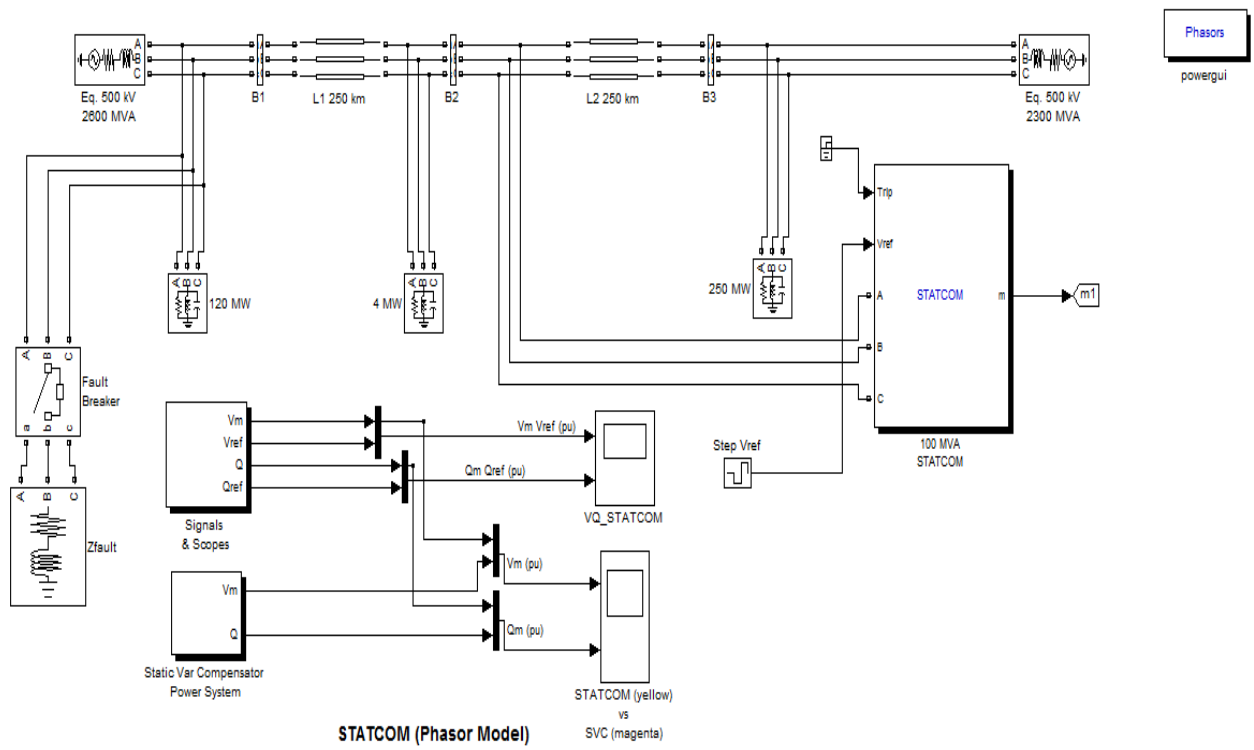

Fig. 3: Simulation test Model

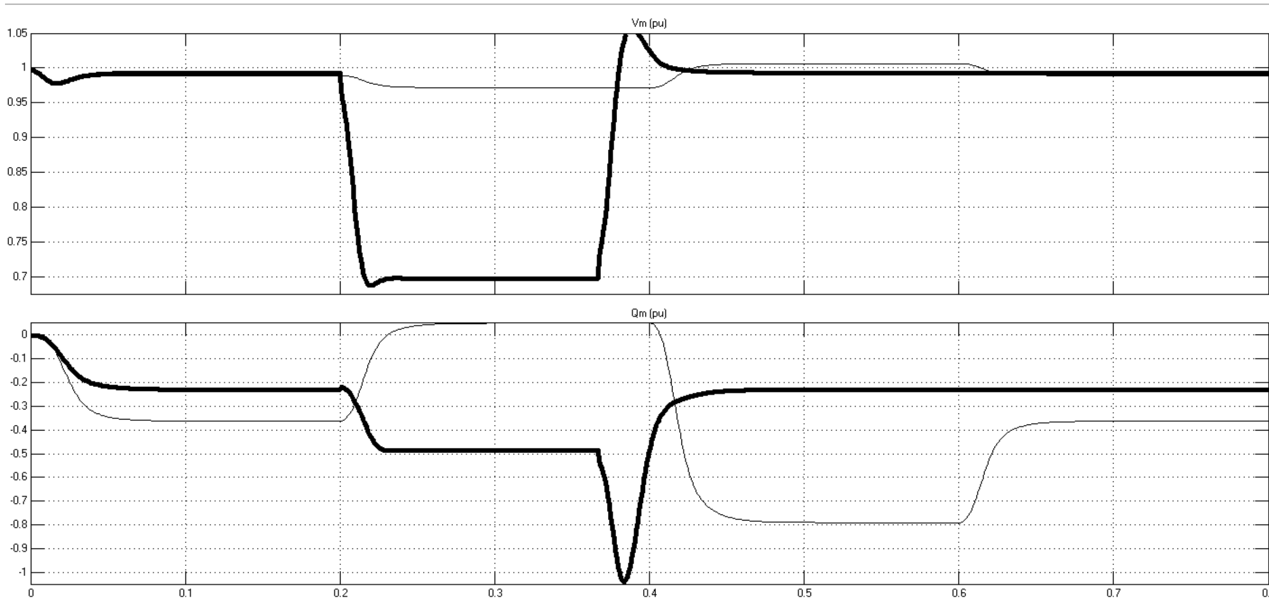

Fig. 4: Graph between STATCOM and SVC

The fig. 5 shows the model of signals and scopes. Here Vabc_B1, Iabc_B1, Vref, Vm, Qref, Qm, Id, Iq, Idref and Iqref are the signals in this model.

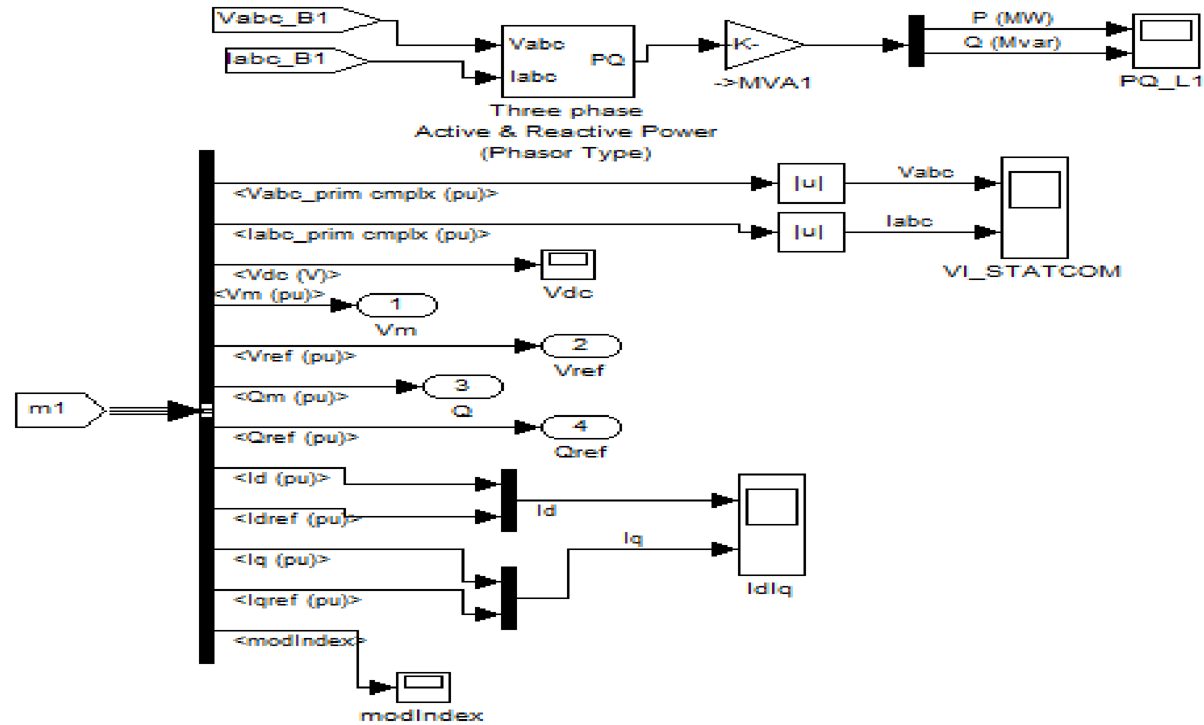

Fig. 5: Signals and Scopes

The Hysteresis Design Tool Model graphis shown in figure 6. The graph is plotted between the Flux (pu) and Current (pu). This graph shows the magnetic effect of current. When the flux is 0, then the current is 0.004 pu. The flux is maximum about 1.2 pu at current 0.015 pu. After this stage value of current starts decreasing w. r. t flux as shown in figure 5. When the flux is 0, current have some negative value.

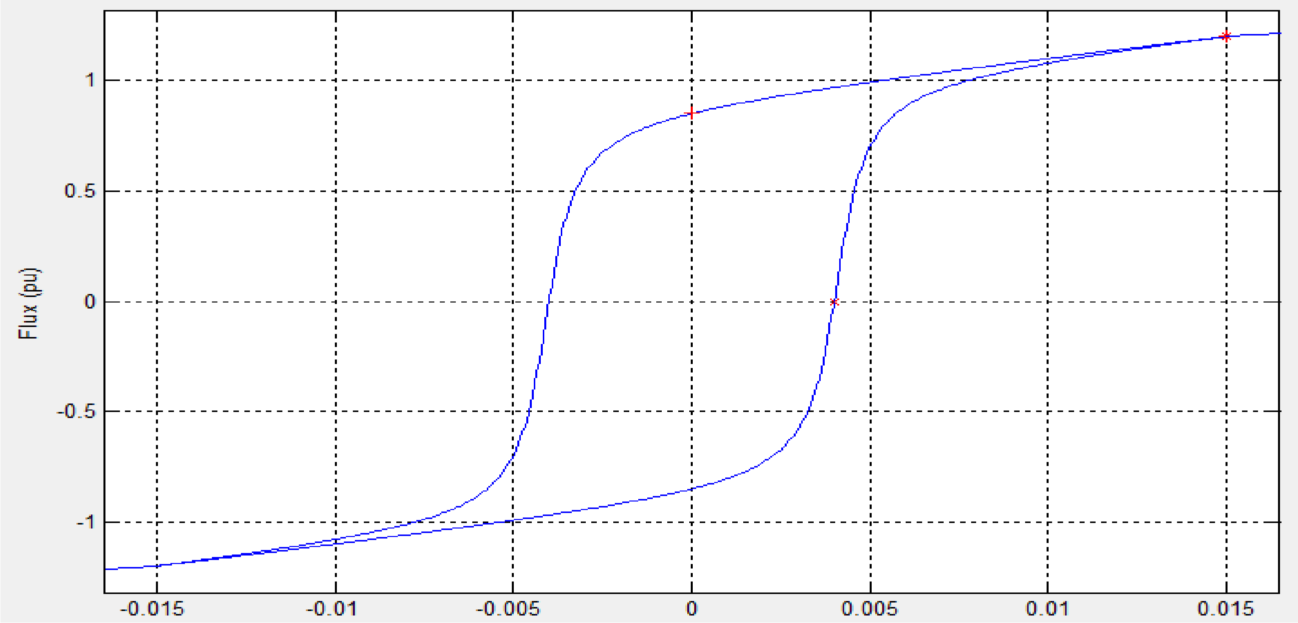

Fig.6: Hysteresis Graph

Table 1 shows the description of blocks, bus type, no of bus, base voltage in pu, reference voltage in pu, active power in MW and reactive power in Mvar and also specifies the name of block and power of load connected. Table 2 shows the steady state voltages and currents with phase angles of different buses. By specify the different phases of different buses, the voltage and currents are obtained with their phase angles. Table 3 shows the system outputs of non-linear elements. The R M S voltages of non-linear elements are given with their phase angles. Table 4 shows the system inputs of non-linear elements. The R M S currents of non-linear elements are given with their phase angles.

	Block type	Bus type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mvar)	Qmin (Mvar)	Qmax (Mvar)	V_LF (pu)	Vangle_LF (deg)	P_LF (MW)	Q_LF (Mvar)	Block Name
1	RLC load	Z	*1*	500.00	1	0.00	250.00	1.35	-Inf	Inf	0.00	0.00	0.00	0.00	250 MW
2	Vsrc	swing	*1*	500.00	1	0.00	0.00	0.00	-Inf	Inf	0.00	0.00	0.00	0.00	Eq. 500 kV 2300 MVA
3	RLC load	Z	*2*	500.00	1	0.00	4.00	0.90	-Inf	Inf	0.00	0.00	0.00	0.00	4 MW
4	RLC load	Z	*3*	500.00	1	0.00	120.00	1.80	-Inf	Inf	0.00	0.00	0.00	0.00	120 MW
5	Vsrc	swing	*3*	500.00	1	0.00	0.00	0.00	-Inf	Inf	0.00	0.00	0.00	0.00	Eq. 500 kV 2600 MVA
6	RLC load	Z	*4*	500.00	1	0.00	250.00	2600.00	-Inf	Inf	0.00	0.00	0.00	0.00	Zfault
7	RLC load	Z	*5*	500.00	1	0.00	250.00	1.35	-Inf	Inf	0.00	0.00	0.00	0.00	Static Var Compensator Power ..
8	Vsrc	swing	*5*	500.00	1	0.00	0.00	0.00	-Inf	Inf	0.00	0.00	0.00	0.00	Static Var Compensator Power ..
9	RLC load	Z	*6*	500.00	1	0.00	4.00	0.90	-Inf	Inf	0.00	0.00	0.00	0.00	Static Var Compensator Power ..
10	RLC load	Z	*7*	500.00	1	0.00	120.00	1.80	-Inf	Inf	0.00	0.00	0.00	0.00	Static Var Compensator Power ..
11	Vsrc	swing	*7*	500.00	1	0.00	0.00	0.00	-Inf	Inf	0.00	0.00	0.00	0.00	Static Var Compensator Power ..
12	RLC load	Z	*8*	500.00	1	0.00	250.00	2600.00	-Inf	Inf	0.00	0.00	0.00	0.00	Static Var Compensator Power ..

Table 1: Load flow Tool Model

1:	'U Static Var Compensator Power System/SVC (Phasor type)1/Vab '	=	486862.39 Vrms	-10.51°
2:	'U Static Var Compensator Power System/SVC (Phasor type)1/Vbc '	=	486862.39 Vrms	-130.51°
3:	'U A: B3 '	=	282360.27 Vrms	-57.91°
4:	'U B: B3 '	=	282360.27 Vrms	-177.91°
5:	'U C: B3 '	=	282360.27 Vrms	62.09°
6:	'U A: B2 '	=	281090.13 Vrms	-40.51°
7:	'U B: B2 '	=	281090.13 Vrms	-160.51°
8:	'U C: B2 '	=	281090.13 Vrms	79.49°
9:	'U A: B1 '	=	277768.59 Vrms	-22.40°
10:	'U B: B1 '	=	277768.59 Vrms	-142.40°
11:	'U C: B1 '	=	277768.59 Vrms	97.60°
12:	'U A: 100 MVA STATCOM/Power Components Modeling (Shunt & Series Converter)/Bus1'	=	281090.13 Vrms	-40.51°
13:	'U B: 100 MVA STATCOM/Power Components Modeling (Shunt & Series Converter)/Bus1'	=	281090.13 Vrms	-160.51°
14:	'U C: 100 MVA STATCOM/Power Components Modeling (Shunt & Series Converter)/Bus1'	=	281090.13 Vrms	79.49°
15:	'U A: Static Var Compensator Power System/B4 '	=	277768.59 Vrms	-22.40°
16:	'U B: Static Var Compensator Power System/B4 '	=	277768.59 Vrms	-142.40°
17:	'U C: Static Var Compensator Power System/B4 '	=	277768.59 Vrms	97.60°
18:	'U A: Static Var Compensator Power System/B5 '	=	281090.13 Vrms	-40.51°
19:	'U B: Static Var Compensator Power System/B5 '	=	281090.13 Vrms	-160.51°
20:	'U C: Static Var Compensator Power System/B5 '	=	281090.13 Vrms	79.49°
21:	'U A: Static Var Compensator Power System/B6 '	=	282360.27 Vrms	-57.91°
22:	'U B: Static Var Compensator Power System/B6 '	=	282360.27 Vrms	-177.91°
23:	'U C: Static Var Compensator Power System/B6 '	=	282360.27 Vrms	62.09°
24:	'I A: B3 '	=	1027.80 Arms	-55.17°
25:	'I B: B3 '	=	1027.80 Arms	-175.17°
26:	'I C: B3 '	=	1027.80 Arms	64.83°
27:	'I A: B2 '	=	1051.86 Arms	-35.67°
28:	'I B: B2 '	=	1051.86 Arms	-155.67°
29:	'I C: B2 '	=	1051.86 Arms	84.33°
30:	'I A: B1 '	=	1088.10 Arms	-17.05°
31:	'I B: B1 '	=	1088.10 Arms	-137.05°
32:	'I C: B1 '	=	1088.10 Arms	102.95°
33:	'I A: 100 MVA STATCOM/Power Components Modeling (Shunt & Series Converter)/Bus1'	=	0.00 Arms	-48.34°
34:	'I B: 100 MVA STATCOM/Power Components Modeling (Shunt & Series Converter)/Bus1'	=	0.00 Arms	-152.68°
35:	'I C: 100 MVA STATCOM/Power Components Modeling (Shunt & Series Converter)/Bus1'	=	0.00 Arms	79.49°

Table 2: Steady state voltages and currents

1:	'U Fault Breaker/Breaker B '	=	277766.04 Vrms	-142.41°
2:	'U Fault Breaker/Breaker C '	=	277766.04 Vrms	97.59°
3:	'U Fault Breaker/Breaker A '	=	277766.04 Vrms	-22.41°
4:	'U Static Var Compensator Power System/Fault Brk/Breaker A '	=	277766.04 Vrms	-22.41°
5:	'U Static Var Compensator Power System/Fault Brk/Breaker B '	=	277766.04 Vrms	-142.41°
6:	'U Static Var Compensator Power System/Fault Brk/Breaker C '	=	277766.04 Vrms	97.59°
7:	'U in phase 1: L2 250 km '	=	281090.13 Vrms	-40.51°
8:	'U in phase 2: L2 250 km '	=	281090.13 Vrms	-160.51°
9:	'U in phase 3: L2 250 km '	=	281090.13 Vrms	79.49°
10:	'U out phase 1: L2 250 km '	=	282360.27 Vrms	-57.91°
11:	'U out phase 2: L2 250 km '	=	282360.27 Vrms	-177.91°
12:	'U out phase 3: L2 250 km '	=	282360.27 Vrms	62.09°
13:	'U in phase 1: L1 250 km '	=	277768.59 Vrms	-22.40°
14:	'U in phase 2: L1 250 km '	=	277768.59 Vrms	-142.40°
15:	'U in phase 3: L1 250 km '	=	277768.59 Vrms	97.60°
16:	'U out phase 1: L1 250 km '	=	281090.13 Vrms	-40.51°
17:	'U out phase 2: L1 250 km '	=	281090.13 Vrms	-160.51°
18:	'U out phase 3: L1 250 km '	=	281090.13 Vrms	79.49°
19:	'U in phase 1: Static Var Compensator Power System/L1 250 km '	=	277768.59 Vrms	-22.40°
20:	'U in phase 2: Static Var Compensator Power System/L1 250 km '	=	277768.59 Vrms	-142.40°
21:	'U in phase 3: Static Var Compensator Power System/L1 250 km '	=	277768.59 Vrms	97.60°
22:	'U out phase 1: Static Var Compensator Power System/L1 250 km'	=	281090.13 Vrms	-40.51°
23:	'U out phase 2: Static Var Compensator Power System/L1 250 km'	=	281090.13 Vrms	-160.51°
24:	'U out phase 3: Static Var Compensator Power System/L1 250 km'	=	281090.13 Vrms	79.49°
25:	'U in phase 1: Static Var Compensator Power System/L2 250 km '	=	281090.13 Vrms	-40.51°
26:	'U in phase 2: Static Var Compensator Power System/L2 250 km '	=	281090.13 Vrms	-160.51°
27:	'U in phase 3: Static Var Compensator Power System/L2 250 km '	=	281090.13 Vrms	79.49°
28:	'U out phase 1: Static Var Compensator Power System/L2 250 km'	=	282360.27 Vrms	-57.91°
29:	'U out phase 2: Static Var Compensator Power System/L2 250 km'	=	282360.27 Vrms	-177.91°
30:	'U out phase 3: Static Var Compensator Power System/L2 250 km'	=	282360.27 Vrms	62.09°

Table: 3 System Outputs of Non Linear Element

1:	'I Fault Breaker/Breaker B '	=	0.00 Arms	0.00°
2:	'I Fault Breaker/Breaker C '	=	0.00 Arms	0.00°
3:	'I Fault Breaker/Breaker A '	=	0.00 Arms	0.00°
4:	'I Static Var Compensator Power System/Fault Brk/Breaker A '	=	0.00 Arms	0.00°
5:	'I Static Var Compensator Power System/Fault Brk/Breaker B '	=	0.00 Arms	0.00°
6:	'I Static Var Compensator Power System/Fault Brk/Breaker C '	=	0.00 Arms	0.00°
7:	'I in phase 1: L2 250 km '	=	99.58 Arms	-103.55°
8:	'I in phase 2: L2 250 km '	=	99.58 Arms	136.45°
9:	'I in phase 3: L2 250 km '	=	99.58 Arms	16.45°
10:	'I out phase 1: L2 250 km '	=	2125.39 Arms	-56.58°
11:	'I out phase 2: L2 250 km '	=	2125.39 Arms	-176.58°
12:	'I out phase 3: L2 250 km '	=	2125.39 Arms	63.42°
13:	'I in phase 1: L1 250 km '	=	101.57 Arms	-114.10°
14:	'I in phase 2: L1 250 km '	=	101.57 Arms	125.90°
15:	'I in phase 3: L1 250 km '	=	101.57 Arms	5.90°
16:	'I out phase 1: L1 250 km '	=	2147.66 Arms	-38.17°
17:	'I out phase 2: L1 250 km '	=	2147.66 Arms	-158.17°
18:	'I out phase 3: L1 250 km '	=	2147.66 Arms	81.83°
19:	'I in phase 1: Static Var Compensator Power System/L1 250 km '	=	101.57 Arms	-114.10°
20:	'I in phase 2: Static Var Compensator Power System/L1 250 km '	=	101.57 Arms	125.90°
21:	'I in phase 3: Static Var Compensator Power System/L1 250 km '	=	101.57 Arms	5.90°
22:	'I out phase 1: Static Var Compensator Power System/L1 250 km'	=	2147.66 Arms	-38.17°
23:	'I out phase 2: Static Var Compensator Power System/L1 250 km'	=	2147.66 Arms	-158.17°
24:	'I out phase 3: Static Var Compensator Power System/L1 250 km'	=	2147.66 Arms	81.83°
25:	'I in phase 1: Static Var Compensator Power System/L2 250 km '	=	99.58 Arms	-103.55°
26:	'I in phase 2: Static Var Compensator Power System/L2 250 km '	=	99.58 Arms	136.45°
27:	'I in phase 3: Static Var Compensator Power System/L2 250 km '	=	99.58 Arms	16.45°
28:	'I out phase 1: Static Var Compensator Power System/L2 250 km'	=	2125.39 Arms	-56.58°
29:	'I out phase 2: Static Var Compensator Power System/L2 250 km'	=	2125.39 Arms	-176.58°
30:	'I out phase 3: Static Var Compensator Power System/L2 250 km'	=	2125.39 Arms	63.42°

Table: 4System Inputs of Non Linear Elements

V. CONCLUSION

An analysis of SVC and STATCOM in static voltage stability enhancement is presented. Both, SVC and STATCOM improve static voltage of the buses. STATCOM provides higher reactive power support with a faster response time but is expensive. SVC, on the other hand, is a cheaper substitute with relatively longer response time. But being capacitor based, the reactive power support to bus falls significantly at the time of fault. Hence, STATCOM provides a robust option. Hence comparison indicates STATCOM is suitable for static as well as dynamic voltage regulation.

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