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Enhancement of Voltage Stability and Reactive Power Control of Multi-Machine Power System Using Facts Devices

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Abstract:-Modern power systems are prone to widespread failures. With the increase in power demand, operation and planning of large interconnected power system are becoming more and more complex, so power system will become less secure. Operating environment, conventional planning and operating methods can leave power system exposed to instabilities. Voltage instability is one of the phenomena which have result in a major blackout. Moreover, with the fast development of restructuring, the problem of voltage stability has become a major concern in deregulated power systems. To maintain security of such systems, it is desirable to plan suitable measures to improve power system security and increase voltage stability margins. FACTS devices can regulate the active and reactive power control as well as adaptive to voltage-magnitude control simultaneously because of their flexibility and fast control characteristics. Placement of these devices in suitable location can lead to control in line flow and maintain bus voltages in desired level and so improve voltage stability margins. Performance evaluation is supported by the simulation results on IEEE 6bus system under different loading conditions using MATLAB.

Keywords:**Flexible AC Transmission System, Static Synchronous Compensator, Static VAR Compensator, MATLAB.**

I. INTRODUCTION

The power system is a highly nonlinear system that operates in a constantly changing environment; loads, generator outputs, topology, and key operating parameters change continually. When subjected to a transient disturbance, the stability of the system depends on the nature of the disturbance as well as the initial operating condition. The disturbance may be small or large. Small disturbances in the form of load changes occur continually, and the system adjusts to the changing conditions. The system must be able to operate satisfactorily under these conditions and successfully meet the load demand. It must also be able to survive numerous disturbances of a severe nature, such as a short circuit on a transmission line or loss of a large generator [1]. Now-a-days it is becoming very difficult to fully utilize the existing transmission system assets due to various reasons, such as environmental legislation, capital investment, rights of ways issues, construction cost of new lines, deregulation policies, etc. Electric utilities are now forced to operate their system in such a way that makes better utilization of existing transmission facilities. Flexible AC Transmission System (FACTS) controllers, based on the rapid development of power electronics technology, have been proposed in recent years for better utilization of existing transmission facilities. With the development of FACTS technique, it becomes possible to increase the power flow controllability and enhance power system's stability. Recently, Flexible Alternative Current Transmission System (FACTS) controllers have been proposed to enhance the transient or dynamic stability of power systems [2]-[3]. Among all FACTS devices, static synchronous compensators (STATCOM) plays much more important role in reactive power compensation and voltage support because of its attractive steady state performance and operating characteristics.

II. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

STATCOM, as shown in Fig.1, is a dynamic compensator consist of a set of voltage source converters (VSC) and a coupling shunt-connected transformer. It is mainly used for power systems dynamic compensation. In fact, STATCOM is a static equivalent of a synchronous compensator; however, the STATCOM is faster in absorbing or providing reactive power as there is no mechanical moving parts involved. In addition, the STATCOM offers more control flexibility in comparison with the synchronous machine. The voltage difference across the coupling transformer results in active and reactive power exchanges between the network and STATCOM.

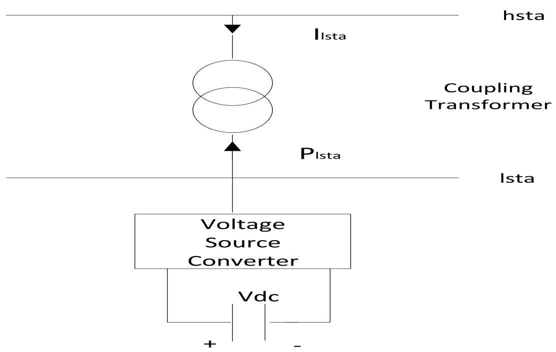

Fig 1: STATCOM Schematic Diagram

The reactive power exchange is achieved by changing the voltage magnitude of voltage source. The active power exchange, used to control the DC voltage of the

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capacitor, in steady- state operation is zero, neglecting the VSC losses [11,12].

III. STATIC VAR COMPENSATOR

Static Var compensator are used by utilities in transmission system or several purpose the main purpose of svc is usually for rapid control of voltage at weak point in a network mainly svc may be installed at the midpoint of the transmission interconnection or at the line ends .static var compensator are shunt connected fact device whose output are varied to control the voltage of the electric power system by generating or absorbing reactive power. Generally SVC is connected as fixed capacitor thyristor control reactor (FC-TCR). The SVC is connected to a coupling transformer that is connected to the bus whose voltage to be improved the reactance of FC-TCR is a varied by firing angle control of ant parallel thyristor firing angle can be controlled through a pi controller in such a way that the voltage of the bus where the svc is connected is maintained as a reference value.

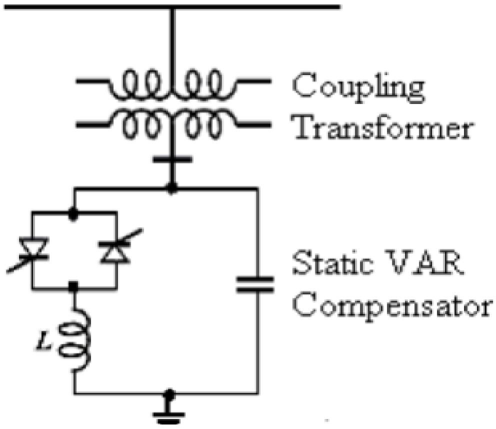

Fig 2 Configuration of SVC

IV. MULTIMACHINE POWER SYSTEM MODEL

A. SIX-BUS TEST SYSTEM

1. Description of the Transmission System

A 6-Bus test system as shown in Fig. 3 is used. The test system consists of three generators and three PQ bus (or load bus). This system which has been made in ring mode consisting of six buses (B1 to B6) connected to each other through three phase transmission lines L12= 450 km, L14= 300km, L15=450 km, L26= 300 km, L23= 450 km, L25=200 km, L24= 250 km, L36= 250 km, L35= 250 km, L45= 350 km, and L56= 150 km, respectively. And the constant loads are connected of 700 MW at bus-4, 500 MW at bus-5 and 250 MW at bus-6 and variable dynamic load 2500+j1000 MVA at bus-6 as shown in Fig.4.14. System has been supplied by three power plants with the phase-to-phase voltage equal to 11 kv. Active and reactive powers injected by power plants 1, 2 and 3 to the power system are presented in per unit by using base parameters Sb=2100 MVA and Vb=400KV, the power plants 1 (G1), 2 (G2) and 3 (G3) generated 1400MVA, 2100 MVA and 700 MVA respectively**.** Here also used HTG Turbine and Regulators subsystems and power system stabilizer as explained above in 6-bus system. The 400 kV 6-bus test systems observe the impact of the FACTS on system stability and power transfer capability. Load flow has been performed with machine G1 defined as a swing bus (V=11000 V, 0 degrees), machine G2 defined as a PV generation bus (V=11000 V, P=1600 MW), and machine G3 defined as a PV generation bus (V=11000 V, P=534 MW). After the load flow has been solved, the reference mechanical powers and reference voltages for the two machines have been automatically updated in the two constant blocks connected at the HTG and excitation system inputs: Pref1=0.750827 pu (1051 MW), Vref1=1.0 pu; Pref2=0.761905 pu (1600 MW), Vref2=1.01 pu; Pref2=0.761905 pu (534 MW), Vref3=1.01 pu.

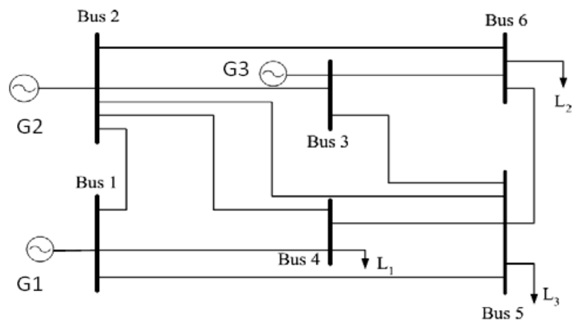

Fig 3 The single line diagram of 6-bus test system.

2 System analysis with-out FACTS

The six bus test system has been simulated here for voltage stability analysis and power transfer capability. The dynamic load is connected at bus-6 for unbalancing in the system. The analysis of system without FACTS is present here for comparative analysis of system performance. The voltage and reactive power value at buses are measure by 'display' block and profile by 'scope' in simulation without FACTS. The PSS (Generic Pa type) are in service. The simulation diagram is shown in fig. 4

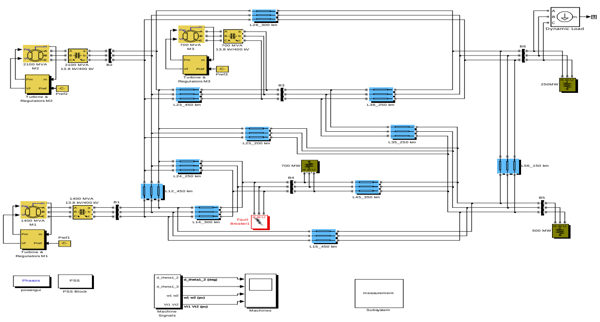

Fig 4. Simulation of Test System with-Out FACT Device

3Impact of SVC

Here observe the impact of the SVC for stabilizing the network during a severe contingency. First put the two PSS in service. Verify that the SVC is in fixed susceptance mode with Bref = 0. The rating of the SVC is

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+/-1000MVA, Start the simulation. Now open the SVC block menu and change the SVC mode of operation to Voltage regulation. The SVC will now try to support the voltage by injecting reactive power on the line when the voltage is lower than the reference voltage (1.0 pu). The chosen SVC reference voltage corresponds to the bus voltage with the SVC out of service. In steady state the SVC will therefore be floating and waiting for voltage compensation when voltage departs from its reference set point. Let we installed SVC at bus 6, as shown. The simulation diagram is shown in fig. 5

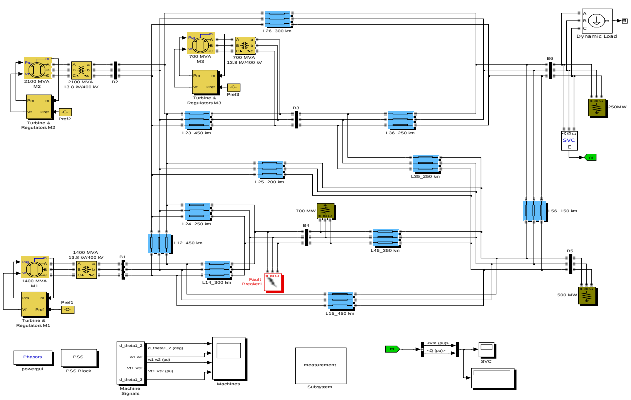


Fig 5 Simulation of Test System with SVC

4. Impact of STATCOM

The Static Synchronous Compensator (STATCOM) is one of the key FACTS devices. STATCOM output current (inductive or capacitive) can be controlled independent of the AC system voltage. The power grid consists of two 400-kV equivalents transmission line. The STATCOM is located at bus-6 (B6) and has a rating of +/- 1000 MVA. This STATCOM is a phasor model of a typical three-level PWM STATCOM. If we open the STATCOM dialog box and select "Display Power data", we will see that our model represents a STATCOM having a DC link nominal voltage of 40 kV with an equivalent capacitance of 375 µF. The simulation diagram is shown in fig. 6.

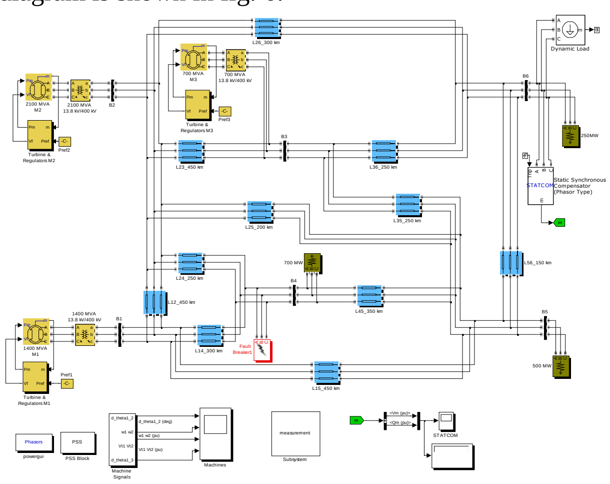
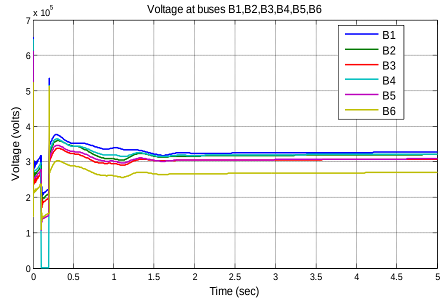


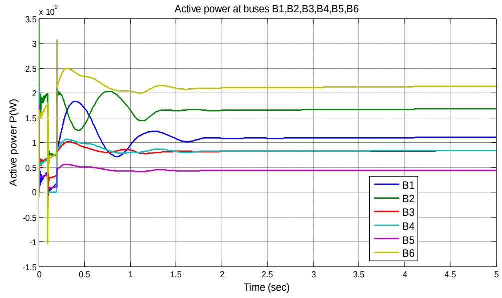
Fig 6.imulation of Test System with STATCOM

V. SIMULATION RESULTS

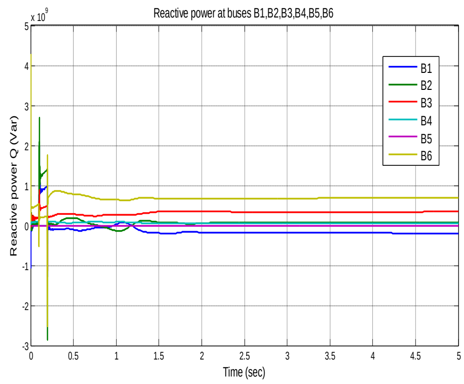
A. With-out FACTS

The simulation results for test system with-out FACT Device are given below. The data for different parameters are given in table 1.





(a) Voltage **(b) Active Power**



(c) Reactive Power

Fig 7. Profiles at buses B1, B2, B3, B4, B5, B6 with-out FACTS, (a) Voltage, (b) Active Power, (c) Reactive Power.

Table -1 Active, Reactive power & voltages with-out FACTS

Bus	P (MW)	Q (Mvar)	S (MVA)	V (k volts)
B1	1106	-193.8	1122.85	327.3
B2	1683	78.07	1684.81	320.4
B3	836.6	341.1	903.47	307.5
B4	841.2	51.37	842.77	322.2
B5	445.7	19.93	446.15	308.4
B6	**2138**	**689.8**	**2246.52**	**269.9**

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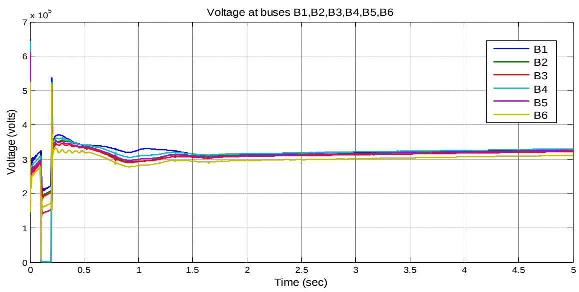
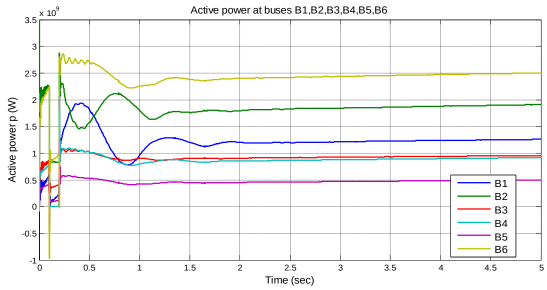
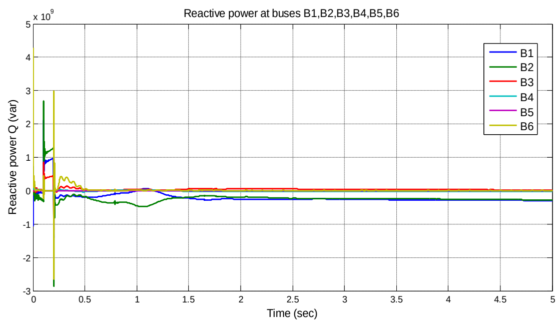
B.With SVC

The simulation results for test system with SVC are given below. The data for different parameters are given in table 2.





(a) Voltage **(b)**Active Power



(c)Reactive Power

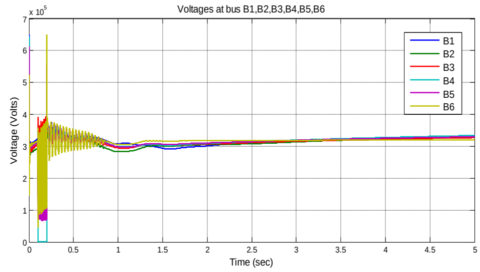
Fig 8.Profiles at Buses B1, B2, B3, B4, B5, B6 With SVC,

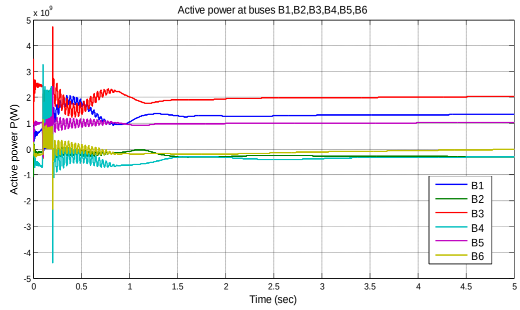
Table -2 Active, Reactive power & voltages with SVC

Bus	P (MW)	Q (Mvar)	S (MVA)	V (k volts)	SVC Data	
					V(pu)	Q(pu)
B1	1257	-294.9	1291.13	327.9	-	-
B2	1908	-275.4	1927.77	325.1	-	-
B3	953.7	23.41	953.99	322	-	-
B4	915.5	-30.28	916.001	330.1	-	-
B5	495.9	41.35	497.62	325.3	-	-
B6	**2499**	**7.571**	**2499.02**	**311.3**	**0.9528**	**0.4323**

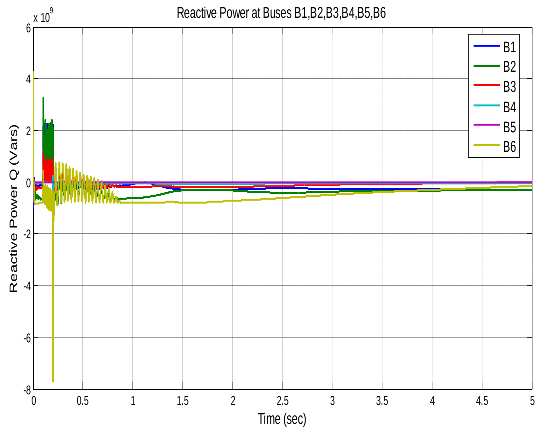
C.With STATCOM

The simulation results for test system with STATCOM are given below. The data for different parameters are given in table 3





(a) Voltage (b)Active Power



(b) Reactive Power

Fig. 9. Profiles at buses B1, B2, B3, B4, B5, B6 with STATCOM

Table -3 Active, Reactive power & voltages with STATCOM

Bus	P (MW)	Q (Mvar)	S (MVA)	V (kvolts)	STATCOM Data	
					V(pu)	Q(pu)
B1	1341	-299.6	1374.06	331.1	-	-
B2	2032	-305.2	2054.79	328.8	-	-
B3	1021	-18.05	1021.16	327.1	-	-
B4	957.5	-41.81	958.42	333.9	-	-
B5	511	-521.5	730.13	330.2	-	-
B6	**2707**	**-164.5**	**2711.994**	**320.4**	**0.9809**	**0.6272**

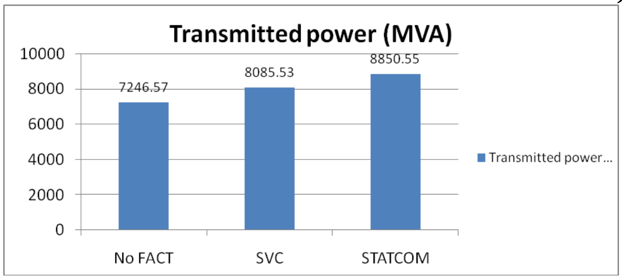


Fig. 10 Waveforms for Transfer Capacity Representation of 6-Bus System

VI. CONCLUSION

This Paper deals with applications of the SVC and STATCOM. The detailed models of the SVC and STATCOM were implemented and tested in MATLAB/simulink environment. The models are applicable for voltage stability analysis, and cover broader range of power transfer capability.

The effects of FACTS (SVC and STATCOM) installed in power transmission path are analyzed in this thesis, and the conclusions are as follow:

1. The STATCOM give superior performance than SVC for reactive power, voltages and power transfer capability for 6-bus system.
2. Similarly the performance enhancement of 6-bus test system can be analyses for compensate reactive power, voltage injected and increased power transfer capability.
3. The best performance has been obtained by introducing FACTS devices such as SVC and STATCOM which compensate reactive power (MVAR), voltage injected (kv) and increased power transfer capability (MVA). It's concluded that by introducing FACTS device system performance, voltage stability and transmission capability improves considerably.

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