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Performance Analysis of Power Flow Control Through Statcom, SVC and UPFC

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ABSTRACT

This paper presents, "Performance Analysis of power flow control through FACTS Devices in Power System. In a power system network consisting of generators, transmission lines, transformers and load etc., STATCOM, SVC and UPFC are applied between two buses separately and their effects are analyzed as par applied system conditions. Power flow between different buses and voltage regulation of above FACTS devices is found out. Simulation of the system was carried out in Matlab environment. In this analysis system was simulated by introducing reference power at the bus where UPFC is connected. UPFC injects series voltage in line and follows reference power as required. SVC and STATCOM are simulated in voltage regulation mode where a reference voltage is given at the bus to which they are connected. Their voltage regulation capabilities and reactive power compensation ability is analyzed.

Keywords **–** STATCOM, SVC, UPFC, Power System

I. INTRODUCTION

Transmission lines in congested areas are often driven increased electric power consumption and trades. Thus, secure operation and reliable supply is endangered by the higher risks for faulted lines. FACTS devices are able to influence power flows and voltages to different degrees depending on the type of the device. If the reactive power of the load is changing rapidly, then a suitable fast response compensator is needed. Static VAR Compensator (SVC), STATCOM and UPFC are such compensators which belong to FACTS family. The ultimate objective of applying reactive shunt compensation in the line is to improve the voltage profile. The inclusion of the FATCS devices in the circuit improves the reactive power in the line. FACTS are successfully simulated and the results show the voltage profile improvement. [1]

Flexible alternating current transmission systems (FACTS) technology opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines. The Unified Power Flow Controller (UPFC) is a second generation FACTS device, which enables independent control of active and reactive power besides improving reliability and quality of the supply. [2]

The power flow over a transmission line depends mainly on three important parameters, namely voltage magnitude of the buses (*V*), impedance of the transmission line (*Z*) and phase angle between buses (θ). The FACTS devices control one or more of the parameters to improve system performance by using placement and coordination of multiple FACTS controllers in large-scale emerging power system networks to also show that the achieve significant improvements in operating parameters of the power systems such as small signal stability, transient stability, damping of power system oscillations, security of the power system, less active power loss, voltage profile, congestion management, quality of the power system, efficiency of power system operations, power transfer capability through the lines, dynamic performances of power systems, and the loadability of the power system network also increased. As FACTS devices are fabricated using solid state controllers, their response is fast and accurate. Thus these devices can be utilized to improve the voltage profile of the system by using coordinated control of FACTS controllers in multi-machine power systems in this work. [3, 4]

II. CONTROL SYSTEM AND MODELLING

Control system and modelling of SVC

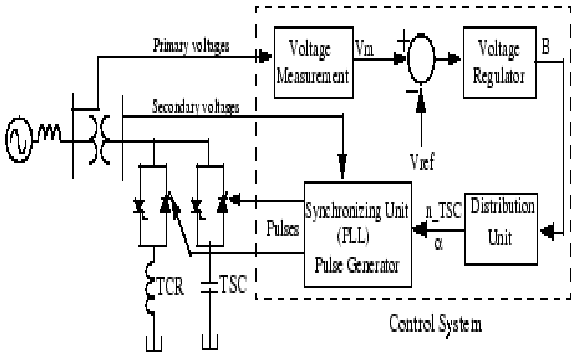

Fig.1 Single-line diagram of an SVC and Its Control System Block Diagram

The control system consists of a measurement system measuring the positive-sequence voltage to be controlled. A Fourier-based measurement system using a one-cycle running average is used. A voltage regulator that uses the voltage error (difference between the measured voltage Vm and the reference voltage Vref) to determine the SVC susceptance B needed to keep the system voltage constant. A distribution unit that determines the TSCs (and eventually TSRs) that must be switched in and out, and computes the firing angle α of TCRs A synchronizing system using a phase-locked loop (PLL) synchronized on the secondary voltages and a pulse generator that send appropriate pulses to the thyristors.[5]

Control system and modelling of STATCOM

The control system consists of a phase-locked loop (PLL) which synchronizes on the positive sequence component of the three phase primary voltage V1. The output of the PLL (angle θ=ωt) is used to compute the direct axis and quadrature axis components of the AC three phase voltage and currents (labeled as Vd, Vq or Id, Iq on the diagram).
Measurement systems measuring the d and q components of AC positive sequence voltage and currents to be controlled as well as the DC voltage Vdc.[10] The output of the AC voltage regulator is the reference current Iq ref for the current regulator (Iq = current in quadrature with voltage which controls reactive power flow). The output of the DC voltage regulator is the reference current Id ref for the current regulator(Id = current in phase with voltage which controls active power flow).An inner current regulation loop consisting of a current regulator. The current regulator controls the magnitude and phase of the voltage generated by the PWM converter (V2d V2q) from the Id ref and Iq ref reference currents produced respectively by the DC voltage regulator and the AC voltage regulator (in voltage control mode). The current regulator is assisted by a feed forward type regulator which predicts the V2 voltage output (V2d V2q) from the V1 measurement (V1d V1q) and the transformer leakage reactance. Control System block diagram is shown in Fig.2

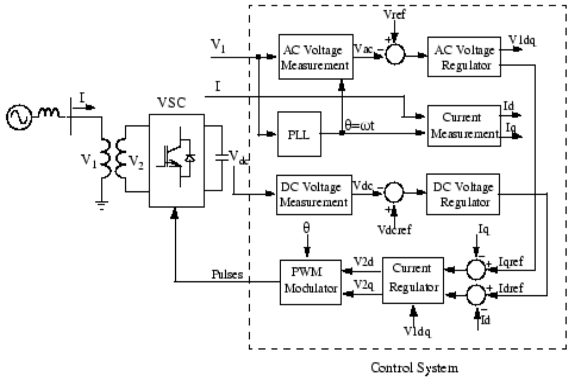

Fig.2 Single-line Diagram of a STATCOM and Its Control System Block Diagram

Control system and modelling of UPFC

Although the UPFC has many possible operating modes, it is anticipated that the shunt inverter will generally be operated in automatic voltage control mode and the series inverter will typically be in automatic power flow control mode. Accordingly, block diagrams are shown in Fig.3 and Fig.4, giving greater detail of the control schemes for each inverter operating in these modes. These control schemes are typical but they may vary in detail from one installation to another. Also, for clarity, only the most significant features are shown and less important signal processing and limiting has been omitted. The control schemes assume that both the series and shunt inverters generate output voltage with controllable magnitude and angle, and that the dc bus voltage will be held substantially constant. [6, 7]

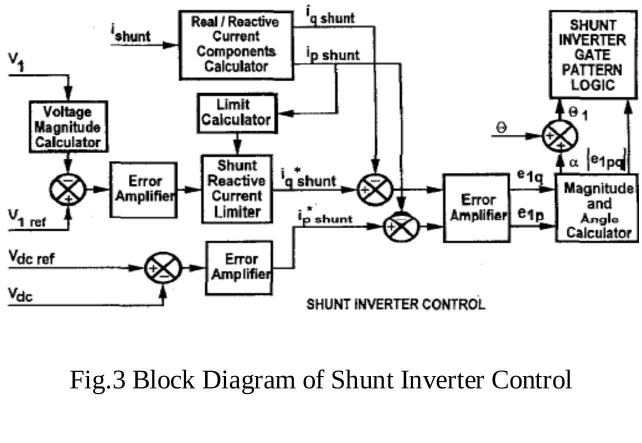

Fig.3 Block Diagram of Shunt Inverter Control

The automatic power flow control for the series inverter is achieved by means of a vector control scheme that regulates the transmission line current, using a synchronous reference frame in which the control quantities appear as dc signals in the steady state The appropriate reactive and real current components are determined for a desired Pref and Qref compared with the measured line currents, and used to drive the magnitude and angle of the series inverter voltage. The series injected voltage limiter in the forward path of this controller that takes account of practical limits on series voltage. [8]

A vector control scheme is also used for the shunt inverter .In this case the controlled current is the current delivered to the line by the shunt inverter. In this case, however, the real and reactive components of the shunt current have a different significance .The reference for the reactive current, iq shunt, is generated by an outer voltage control loop, responsible for regulating the ac bus voltage, and the reference for the real-power bearing current, ip shunt, is generated by a second voltage control loop that regulates the dc bus voltage .In particular, the real power negotiated by the shunt inverter is regulated to balance the dc power from the series inverter and maintain a desired bus voltage. The dc voltage reference, Vdc may be kept substantially constant .For the shunt inverter the most important limit is the limit on shunt reactive current as a function of the real power being passed through the dc bus .This prevents the shunt inverter current reference from exceeding its maximum rated value. The control block diagrams shown in Fig.3 and Fig.4 are only a small part of the numerous control algorithms that are needed for all the operating modes of the UPFC, and for protection and sequencing. The control system typically incorporates many sophisticated computers and extensive electronics.[9]

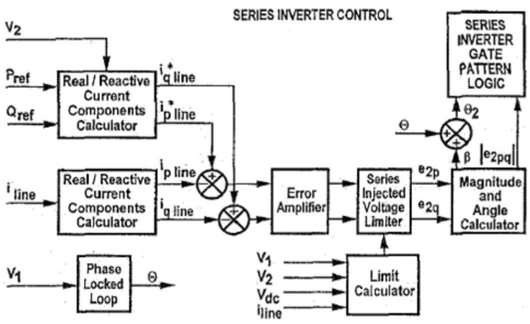

Fig.4 Block diagram of series inverter Control

III. SIMULATION RESULTS

SVC Simulation Results

SVC acts basically in Voltage Regulation and VAR control mode .For the selected power system network, result of Voltage Regulation mode has been found out. [10, 11]

Voltage Regulation

In the Fig.5 results of applied reference voltage and measured reference voltage at SVC Bus is shown. Here SVC shows its voltage regulation capability.

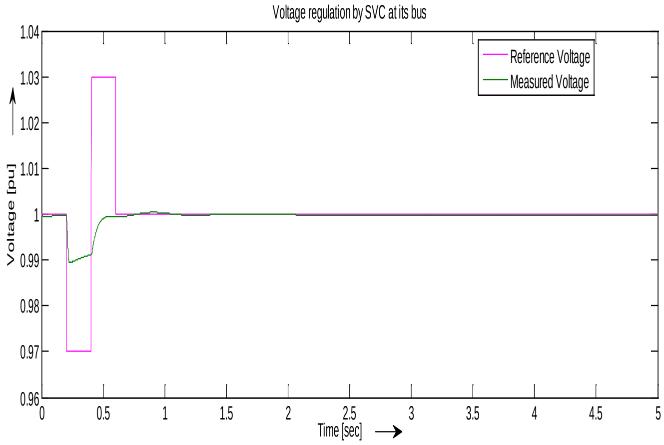

Fig.5 Reference Voltage and measured voltage at SVC Bus.

In Fig.6 Reactive power supplied by SVC is shown during voltage regulation.

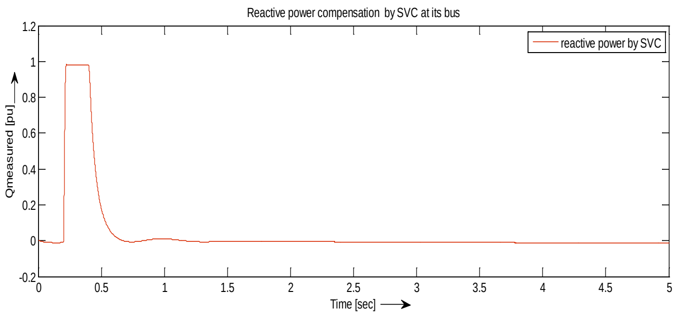

Fig.6 Reactive power supplied by SVC during voltage regulation

STATCOM Simulation Results

Simulation results of STATCOM are shown in Fig.7 when it is connected to Bus B_1.

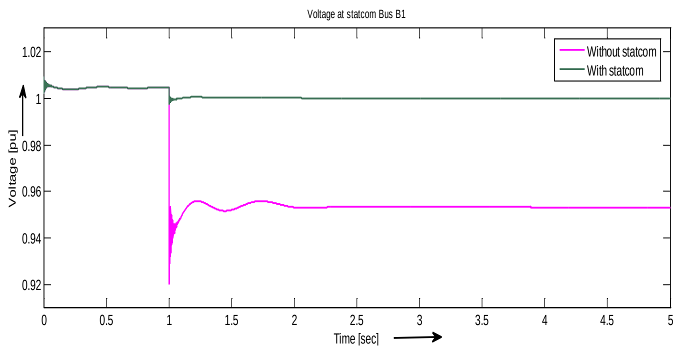

Fig.7 STATCOM connected at Bus B_1

Voltage Regulation at Bus B_2

Simulation results of STATCOM are shown in Fig.8 when it is connected to Bus B_2.

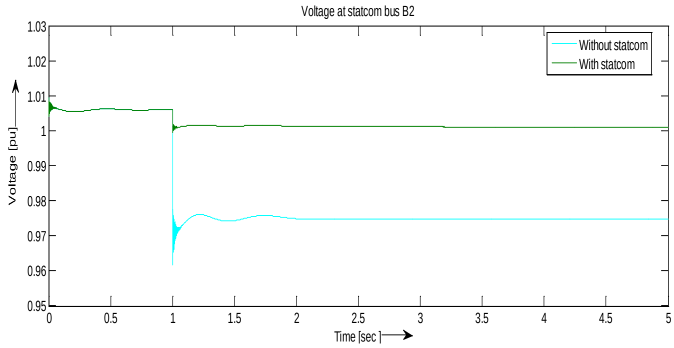

Fig.8 STATCOM connected at Bus B_2.

Voltage Regulation at Bus B_3

Simulation results of STATCOM are shown in Fig.9 when it is connected to Bus B_3.

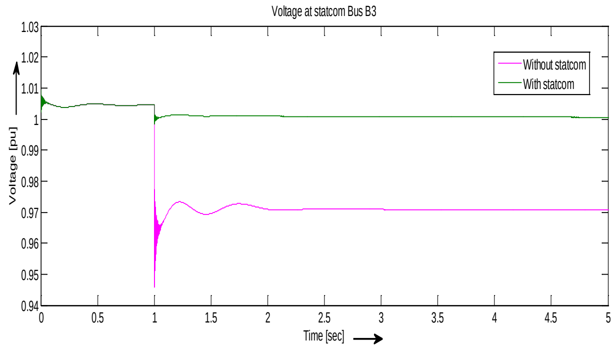

Fig.9 STATCOM connected at Bus B_3.

Voltage Regulation at Bus B_4

Simulation results of STATCOM are shown in Fig.10 when it is connected to Bus B_4

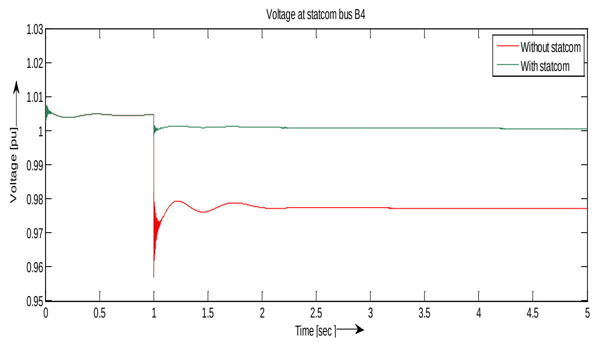

Fig.10 STATCOM connected at Bus B_4

Voltage Regulation at Bus B_5

Simulation results of STATCOM are shown in Fig.11 when it is connected to Bus B_5.

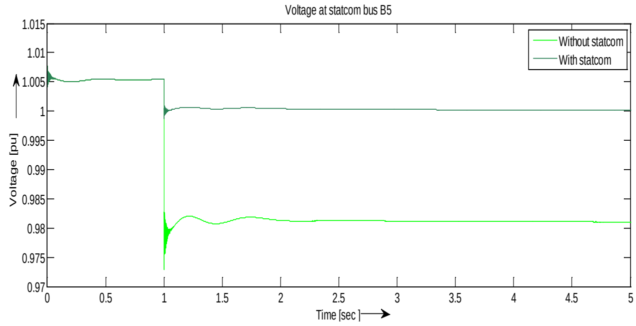

Fig.11 STATCOM connected at Bus B_5

Simulation Results of UPFC

UPFC simulation results for change in active power demand, reactive power demand and corresponding value of magnitude and phase angle of injected voltage are found out. [12, 13]

Simulation results for step like changes in Active Power at UPFC Bus

Fig.12 shows step like change in reference active power and response of UPFC to meet this demand.

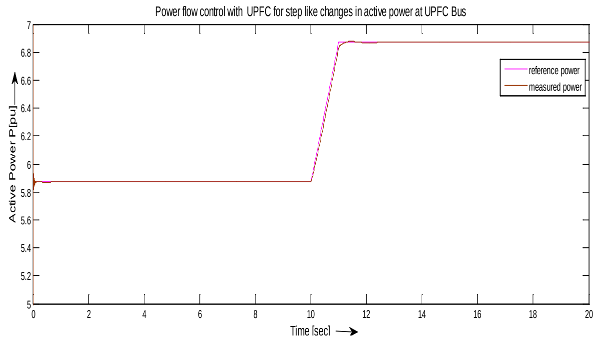

Fig.12 Reference active power with measured active power at UPFC Bus

Simulation results for step like changes in Reactive Power at UPFC Bus.

Fig.13 shows step like change in reference reactive power and response of UPFC to meet this demand.

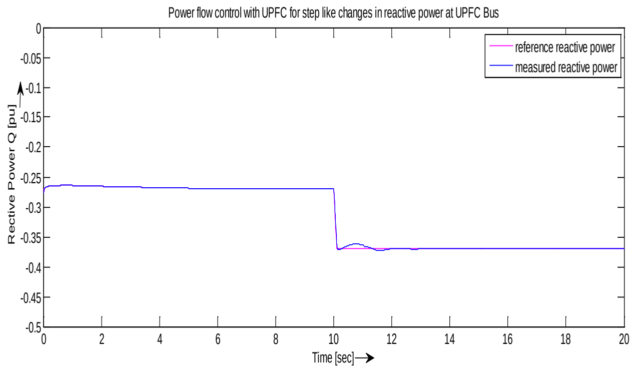

Fig.13 Reference reactive power with measured active power at UPFC Bus

Simulation results for UPFC injected Voltage Magnitude and phase angle.

Fig.14 and Fig.15 shows UPFC injected voltage magnitude and phase angle to meet the demand in active and reactive power.

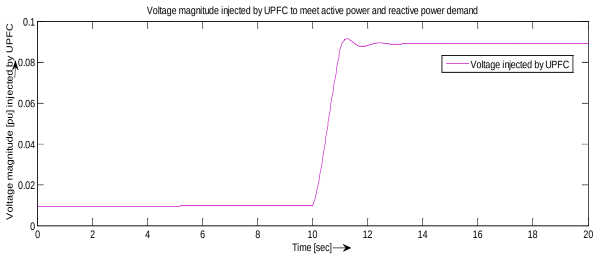

Fig.14 Voltage magnitude injected by UPFC

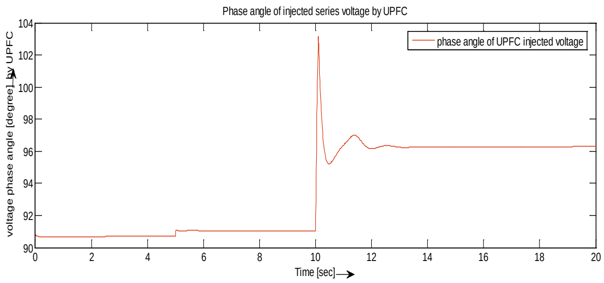

Fig.15 Phase angle of injected series voltage at UPFC Bus

IV.Active and Reactive Power Flow Comparison

For the given power system network power flow comparison is being carried out. When UPFC is not connected to the system transformer2 of 800 MVA capacity is overloaded by 99 MW.UPFC handles this congestion situation and relieves transformer 2 to draw only 796 MW through it. It forces UPFC Bus to draw extra active power through it.

Table1. Comparison of active and reactive power flow with and without UPFC

S.No	UPFC	B_1B_2	B_2B_3	B_3B_5	B_4B_5	B_4B_5+ B_3B_5
1	Not Connected	95.19 MW	588.8 MW	586.8 MW	898.6 MW	1279 MW
		-16.4 Mvar	-63.69 Mvar	-26.83 Mvar	26.72 Mvar	-105.6 Mvar
2	Connected	196.6 MW	689.7 MW	687 MW	796 MW	1277 MW
		-31.82 Mvar	-99.45 Mvar	-37 Mvar	18 Mvar	-97.1 Mvar

Thus results in above table of UPFC is showing relieve in congestion between BUS B_4 and BUS B_5 and now transformer2 is not overloaded.

V. CONCLUSIONS

UPFC can control active and reactive power flow in transmission lines. SVC and STATCOM improves system voltage stability. Voltage regulation mode of SVC and STATCOM is successfully simulated in MATLAB. Simulation results are good and they are accepted. UPFC can control active power and reactive power independently. Series compensator of UPFC can be operated in power flow control mode and simultaneously shunt compensator may be operated in voltage regulation or var control mode. Similarly, simulations carried out showed that SVC and STATCOM provides excellent voltage regulation, power factor and active power regulation capabilities.

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