

STATIC ANALYSIS OF STATCOM FOR ENHANCEMENT OF VOLTAGE ON TRANSMISSION LINE

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Abstract: The recent development of Power- Electronics controller introduces the use of various FACTS devices in power systems networks. FACTS devices can control the power system network condition in expediting manner and this feature of FACTS devices can be demoralizing to improve the steady state stability of a system. This paper aims to investigate the static analysis based on a 6-pulse voltage-source converter for Static Synchronous Compensator (STATCOM). A 3-bus system has been used for the proposed STATCOM model. The STATCOM model and its simulation are performed using MATLAB's Simulink and Power System Blockset. Static analysis is done for STATCOM to verify its capability in improving voltage regulation in the transmission systems.

Keywords: STATCOM, Steady state analysis, Multilevel Converter, Transmission line.

1. INTRODUCTION

In this fastest growing world, the utility transmission systems are reaching their limits, making for reliable power greater than ever. Due to deregulation, the need for a new power flow controller are in great demand. Hence, new controllers should be able to control voltage level and enhance the power flow capability of transmission line to their secure loading with no changes of system stability and security margins. One such controller is called as FACTS controllers which has the ability of enhancing transmission system control, reliability, and operation, and also improves the distribution-system power quality.

It is based on power-electronic controllers, which enhance the value of transmission networks by increasing the use of their capacity. As these controllers operate very fast and they enlarge the safe operating limits of a transmission system without risking stability. Today, it is expected that within the voltage limits of

electrical insulating devices, the operating constraints of the current-carrying thermal limits of conductors, and the structural limits of the supporting infrastructure, an operator should be able to control power flows on lines to secure the highest safety margin as well as transmit electrical power at a minimum of operating cost. FACTS controllers enhance the high speed and precise control of one or more AC system parameters within a synchronous AC system, thereby greatly increasing the value of AC transmission assets. These parameters include voltages, impedances, phase angle, currents, reactive power and active power.

Static Synchronous Compensator or STATCOM is one of the FACTSs' families. STATCOM gives improved voltage and power system stabilization and enhanced reliability. In this paper, the steady state performance of a STATCOM based on a 6-pulse voltage-source converter has been investigated. To demonstrate the potential of this control, one test system which is 3-bus systems have been used to validate the proposed model. Using MATLAB's Simulink, the STATCOM model and the detailed simulation are performed. In order to

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verify the capability of the STATCOM in improving voltage regulation, steady state analysis is done with the transmission systems.

2. STATCOM

The Static Synchronous Compensator (STATCOM) is one of the new generation Flexible AC Transmission Systems (FACTS) devices with advanced future applications. There are two basic controls which can be implemented in the STATCOM. One is the AC voltage regulation of the power system at the bus bar where the STATCOM is installed and another is the control of the DC voltage across the DC capacitor inside the STATCOM. AC voltage regulation is realized by controlling the reactive power interchange between the STATCOM and a power system. If the STATCOM converter is based on Pulse Width Modulation (PWM) algorithm, the DC voltage across the DC capacitor must be constant. It has been suggested that two individual controllers are assigned to these two STATCOM functions. However, from the point of view of control system design, a power system installed with the dual function STATCOM is a two-input two-output multivariable system when both STATCOM AC and DC voltage controls are implemented. Hence closed-loop system stability can only be guaranteed when AC and DC voltage regulators are designed by jointly.

3. OPERATING PRINCIPLE OF STATCOM

STATCOM is a converter type FACTS device, which provides superior performance characteristics, compared with conventional compensation methods employing thyristor-switched capacitors and thyristor-controlled reactors.

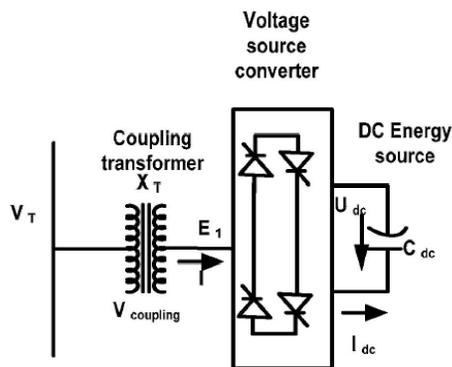


Fig.1 Static synchronous Compensator

The schematic diagram of a STATCOM is shown in Fig 1. The charged capacitor C_{dc} , provides a DC voltage to the converter, which produces a set of controllable three-phase output voltages synchronous with the AC power system. By varying the amplitude of the output voltage, the reactive power exchange between the converter and the AC system can be controlled. If the amplitude of the output is increased above the AC system voltage V_T current flows through the reactance of the coupling transformer and a leading current is produced, i.e. the STATCOM is seen as a capacitor mode by the AC system and reactive power is generated. By decreasing the amplitude of the output voltage below that of the AC system, a lagging current results and the STATCOM are seen as an inductor mode. In this case reactive power is absorbed. If the amplitudes are equal no power exchange takes place.

4. V-I CHARACTERISTICS OF STATCOM

Multilevel Inverter is one of the most vital topology in the family of cascade Multilevel Inverters. In further, the Multilevel Inverters are classified into (i) Diode-clamped, (ii) Flying capacitors and (iii) Cascade multilevel inverter (CMLI). CMLI has a modular structure and requires the least number of components as compared to other two topologies. The VSI has the same rated-current capability when it operates with the capacitive- or inductive-reactive current. Therefore, a VSI having a certain MVA rating gives the STATCOM twice the dynamic range in MVAR.

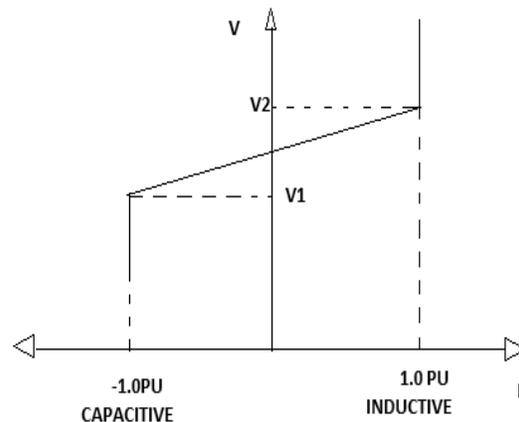


Fig.2. V-I Characteristics of STATCOM

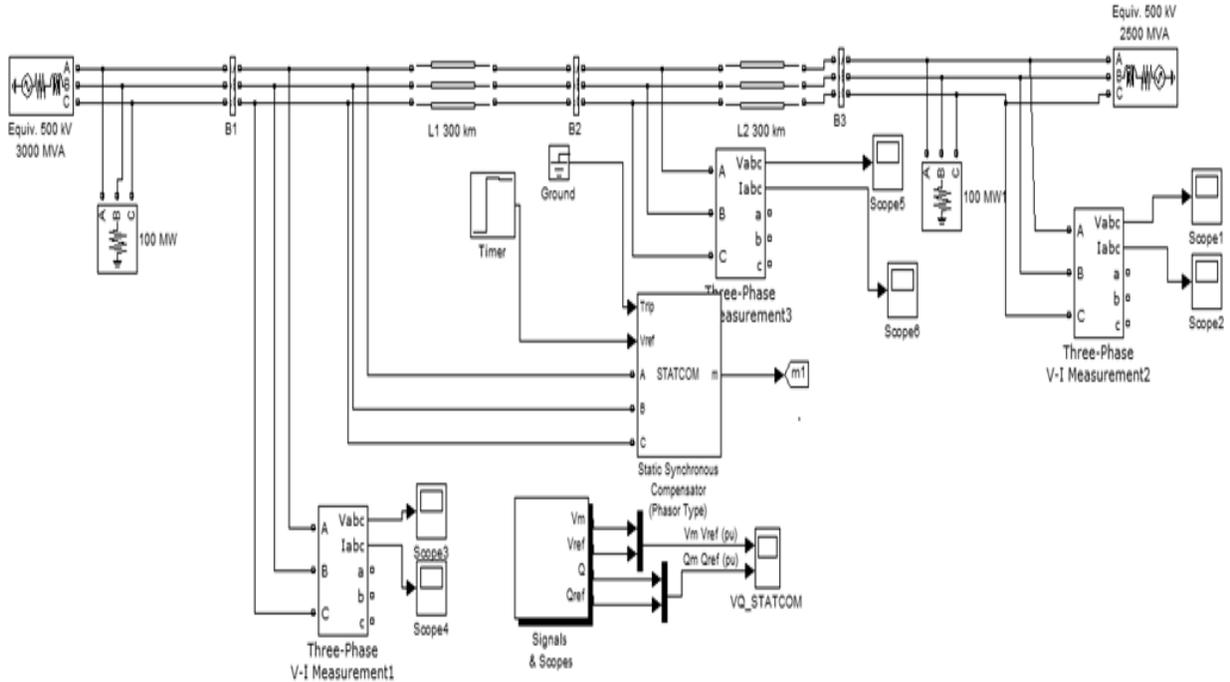
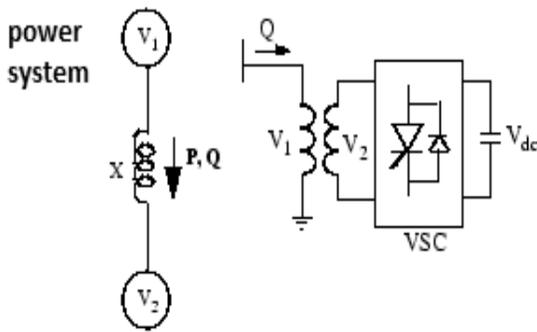


Fig.4.Simulation circuit of three bus system with STATCOM



V_2 = Line to Line voltage of source V_2
 X = Reactance of interconnection transformer and filters
 δ = Angle of V_1 with respect to V_2

5. STATCOM-STEADY STATE ANALYSIS

$$P = \frac{V_1 V_2 \sin \delta}{X} \dots \dots \dots (1)$$

$$Q = \frac{V_1 (V_1 - V_2 \cos \delta)}{X} \dots \dots \dots (2)$$

Where

V_1 = Line to Line voltage of source V_1

The steady state analysis of STATCOM is shown in Fig.3. During steady state operation, the V_2 voltage generated by the VSC is in phase with V_1 ($\delta=0$), so that only reactive power is flowing ($P=0$). If V_2 voltage is lower than V_1 , Q is flowing from V_1 to V_2 (STATCOM is absorbing reactive power). On the reverse, if V_2 voltage is higher than V_1 , Q is flowing from V_2 to V_1 (STATCOM is generating reactive power). The amount of reactive power is given by a capacitor connected to the DC side of the VSC that acts as a DC voltage source. Under steady state, the voltage V_2 has to be phase shifted slightly behind V_1 in order to compensate for transformer and VSC losses and keep the capacitor charged.

The steady state analysis of STATCOM can be performed in two different modes, (i) In voltage regulation mode (the voltage is regulated within limits) (ii) In Var control mode (the STATCOM reactive power output is kept constant)

6. DESCRIPTION OF THE SYSTEM

The simulation diagram of the three bus power transmission systems, with STATCOM is shown in Fig. 4. It has two sources units (1400 MVA and 700 MVA) and two load units (1300 MW and 1500 MW) with a 500 km long transmission line. The suitable location of STATCOM is selected by referring to the critical bus where the voltage magnitude is less than 5% of the rated voltage.

Four cases are studied via time simulation under steady state conditions for the proposed power transmission system in the Fig. 4. The four cases are:

Case 1, Without any controllers in the system;

Case 2, With STATCOM at the near busB2 (Midpoint Connection);

Case 3, With STATCOM at the near busB1 (Left side Connection);

Case 4, With STATCOM at the near busB3 (Right side Connection).

7. SIMULATION RESULTS

A typical three-level PWM type, 500 KV and +/-100 MVAR STATCOM connected at the Midpoint of the power system is shown in Fig.4. Based on a voltage-sourced converter, the STATCOM regulates the system voltage by absorbing or generating reactive power. STATCOM output current (inductive or capacitive) can be controlled independently of the AC system voltage. In this analysis three installation positions have been considered for the STATCOM (Midpoint Connection, Left side connection, Right side connection).

It can be shown from the Fig.6, when STATCOM is applied to the system, the magnitude voltage of bus 1, 2, 3 is extensively increased. The reactive power is actually increasing at the affected line and as a result the STATCOM is supplying the Vars to the system. It is observed that the STATCOM is in the capacitive mode of operation when the reactive power flows from the converter to the system.

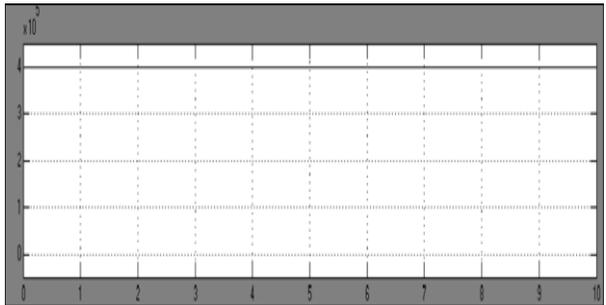
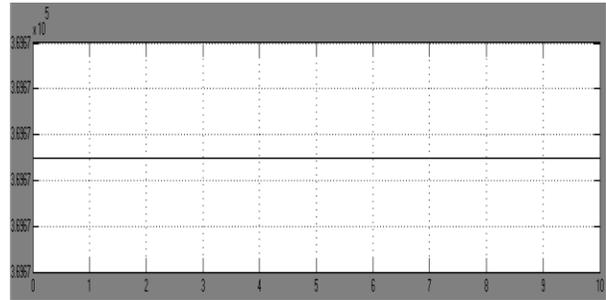
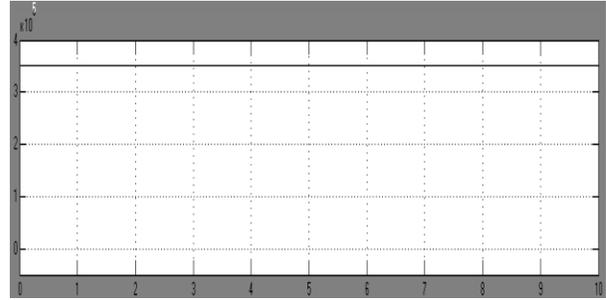


Fig.5 Voltage waveforms without STATCOM

- (i) Voltage at Bus B1
- (ii) Voltage at Bus B2
- (iii) Voltage at Bus B3

From Fig.5, the voltages at all the buses is noted down without connecting STATCOM. From Fig.6, the voltage at all the buses with STATCOM connection is noted and it shows that the Midpoint connection has high voltage compared to other two buses. The Comparison Result for the three bus systems are given in Table I.

Parameter	Volt at Bus B1 (pu)	Volt at Bus B2 (pu)	Volt at Bus B3 (pu)
Without STATCOM	0.65	0.70	0.74
With STATCOM Midpoint connection	0.89	0.94	1.0
With STATCOM Left connection	0.66	0.74	0.77
With STATCOM Right connection	0.84	0.9	0.98

TABLE I - Comparison Result for the Three Bus Systems

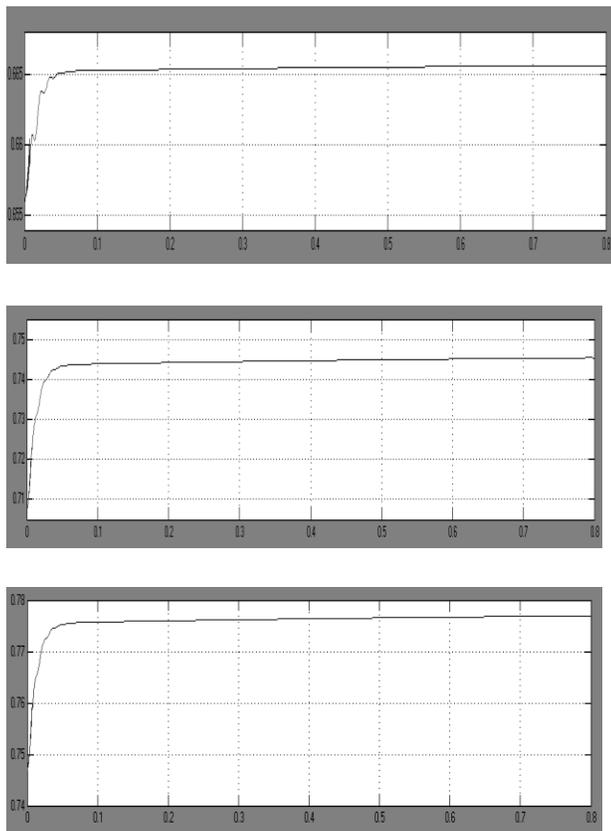


Fig.6 Voltage waveforms with STATCOM

- (i) Voltage at Bus B1
- (ii) Voltage at Bus B2
- (iii) Voltage at Bus B3

8. CONCLUSION

In this paper a six-pulse using a three-level voltage-sourced converter and PWM-based STATCOM controller is successfully modeled. The steady state performance of the STATCOM is performed using Matlab/Simulink Environment. The simulation of STATCOM has demonstrated that STATCOM can be effectively applied in power transmission networks to solve the issues of poor dynamic performance and voltage regulation in the power transmission system. It is shown that STATCOM provide better performance in the enhancement of voltage regulation in a power system and STATCOM is most effective when connected at the Midpoint of a transmission system.

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