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# Static Analysis of Statcom for Enhancement of Voltage on Transmission Line

*G. Sundar, M. Rekha and M. Jayanthi*

Department of Electrical Engineering,
Arulmigu Meenakshi Amman College of Engineering, Kanchipuram, TamilNadu, India

**Abstract:** This paper aims to investigate the static analysis based on a 6-pulse voltage-source inverter for Static Synchronous Compensator (STATCOM). 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. 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.

**Key words:** STATCOM · Steady state analysis · Multilevel Inverter · Transmission line

## 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 is 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 boosting transmission system control, dependability, operation and also improves the distribution-system power quality [1].

It is based on power-electronic controllers, which increase the value of transmission networks enhancing their capacity. These controllers operate very fast and also improve the safe operating limits (SOL) of the transmission system without risking its 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 accompanying frame, an operator ought to be able to supervise power flow on lines to secure the highest safety margin as well as convey electrical power at a least of functional 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. These parameters include voltage, currents, impedance, phase angle, reactive power and active power [2].

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 inverter 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 verify the capability of the STATCOM in improving voltage regulation, steady state analysis is done with the transmission systems [3].

**Static Synchronous Compensator (Statcom):** The Static Synchronous Compensator (STATCOM) is Flexible AC Transmission Systems (FACTS) devices with advanced future applications. There are two basic controls which can be tooled in the STATCOM. 1) The AC voltage regulation of the power system at the bus bar where the STATCOM is mounted. 2) The control of the DC voltage

**Corresponding Author:** G. Sundar, Department of Electrical Engineering, Arulmigu Meenakshi Amman College of Engineering, Kanchipuram, TamilNadu, India.

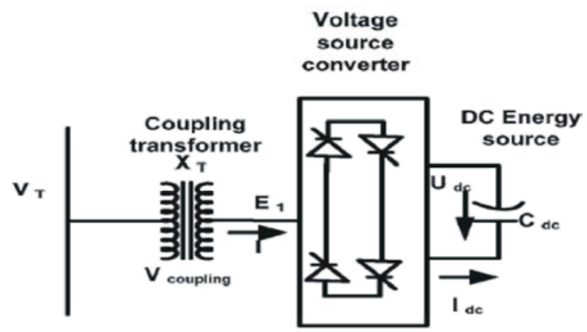


Fig. 1: Static synchronous Compensator

across the DC capacitor inside the STATCOM. AC voltage regulation is brought to fruition by manipulating the reactive power swapping between the STATCOM and a power system. If the STATCOM inverter is based on Pulse Width Modulation (PWM) technique, the DC voltage across the 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 restrain are instigated. Hence closed-loop system steadiness can only be guaranteed when AC and DC voltage regulators are designed in conjunction [4].

**Operating Principle of Statcom:** STATCOM is a inverter type FACTS device, which provides superior performance characteristics, compared with established recompense methods employing thyristor-switched capacitors (TSC) and thyristor-controlled reactors (TCR)[5].

The schematic diagram of a STATCOM is shown in Fig. 1. The charged capacitor *Cdc*, provides a DC voltage to the inverter, which bring in to being a group of controllable three-phase output voltage, synchronous with the AC power system. By varying the bounty of the yield voltage, the reactive power interaction between the inverter and the AC system can be limited. If the bounty of the output is boosted above the AC system voltage VT 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 reducing the bounty of the output voltage below that of the AC system, a lagging current yield and the STATCOM are seen as an inductor mode. In this case reactive power is riveted. If the amplitudes are equal no power exchange takes place [6].

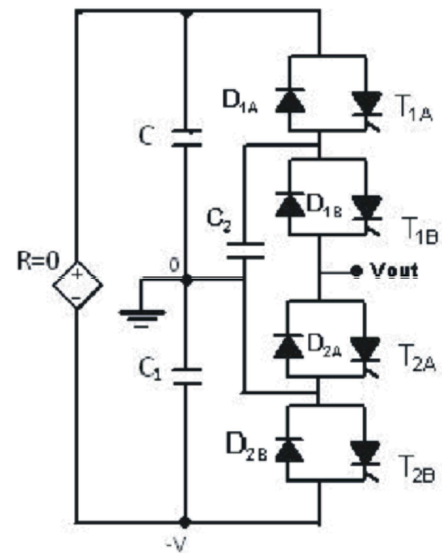


Fig. 2: Three Level Inverter

**Multilevel Inverter Statcom:** Cascade Multilevel Inverter is one of the most important topology in the family of 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 competence when it functions with the capacitive- or inductive-reactive current. Therefore, a VSI having certain MVA rating gives the STATCOM twice the dynamic range in MVAR [7].

The schematic diagram of one leg of three level-inverter is shown in Fig. 2. It comprises of four switches per leg and two main diodes. Each of the switches contains of a power semiconductor device and an anti-parallel diode. The single PWM approach is used to generate the gating pulses for the switches $T_{1A}$, $T_{1B}$, $T_{2A}$ and $T_{2B}$. The Three level-inverter could produced a three different voltage levels of +V, 0 and –V. These voltage levels can be obtained using two equal capacitors. The proposed three-level STATCOM shown in Fig. 2. is simulated using the MATLAB/Simulink software. The switching states and voltage levels of the capacitor clamped three level-inverter as tabulated in Table 1 [8-12].

**Statcom – Steady State Analysis:** The steady state analysis of STATCOM is shown in Fig. 3. During steady state operation, the $V2$ voltage generated by the VSC is in phase with $V1$ ($\delta$ = 0), so that only reactive power is flowing ($P$ = 0). If $V2$ voltage is lower than $V1$, Q is flowing from $V2$ to $V1$ (STATCOM is captivating reactive power).

Table 1: Switching states and voltage levels of the three level inverter

| | Switching states | | | |
|---|---|---|---|---|
| Voltage levels $V_{out}$ | $T_{1A}$ | $T_{1B}$ | $T_{2A}$ | $T_{2B}$ |
| +V | ON | ON | OFF | OFF |
| 0 | OFF | ON | ON | OFF |
| -V | OFF | OFF | ON | ON |

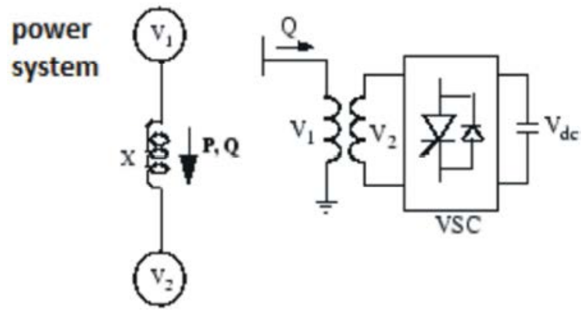


Fig. 3: Steady state analysis of STATCOM

On the reverse, if $V2$ voltage is higher than $V1$, Q is flowing from $V2$ to $V1$ (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 $V2$ has to be phase shifted slightly behind $V1$ in order to compensate for transformer and VSC losses and keep the capacitor charged [13].

$$P = \frac{V_1 - V_2 \sin\delta}{X} \tag{1}$$

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

where,

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

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 yield is kept constant)[14].

**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 [15].

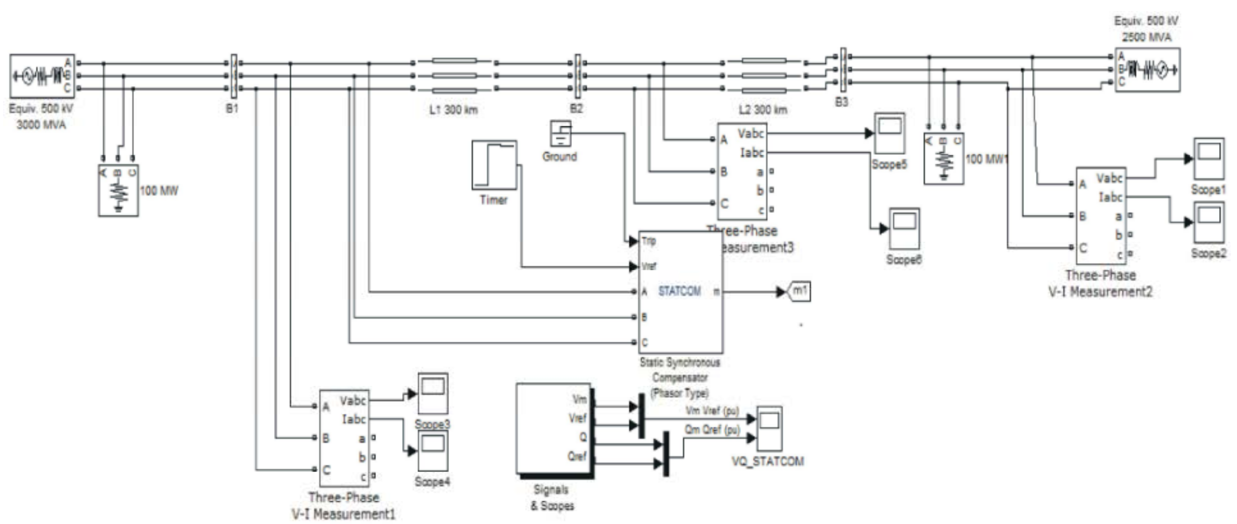


Fig. 4: Simulation circuit of three bus system with STATCOM

Table 2: Comparison Result for the Three Bus Systems

| S.No | Status of STATCOM | Volt at Bus B1 (pu) | Volt at Bus B2 (pu) | Volt at Bus B3 (pu) |
|---|---|---|---|---|
| 1 | Without STATCOM | 0.65 | 0.70 | 0.74 |
| 2 | With STATCOM Midpoint connection | 0.89 | 0.94 | 1.0 |
| 3 | With STATCOM Left connection | 0.66 | 0.74 | 0.77 |
| 4 | With STATCOM Right connection | 0.84 | 0.9 | 0.98 |

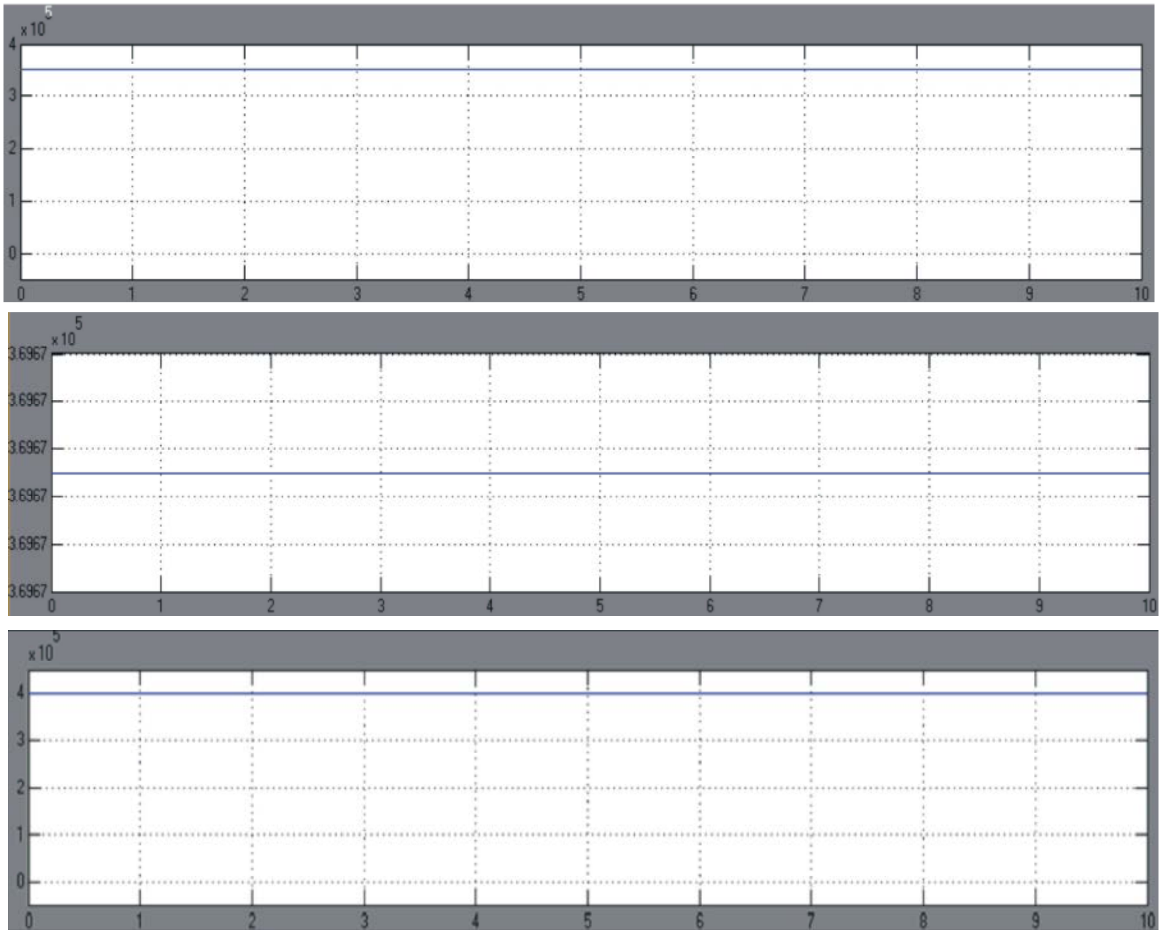


Fig. 5: Voltage waveforms without STATCOM
(i) Voltage at Bus B1
(ii) Voltage at Bus B2
(iii) Voltage at Bus B3

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).

**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 inverter, the STATCOM regulates the system voltage by absorbing or generating reactive power. STATCOM output current (inductive or capacitive) can be contained 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).

From Fig.5, the voltages at all the buses is noted down without connecting STATCOM. 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 inverter to the system.

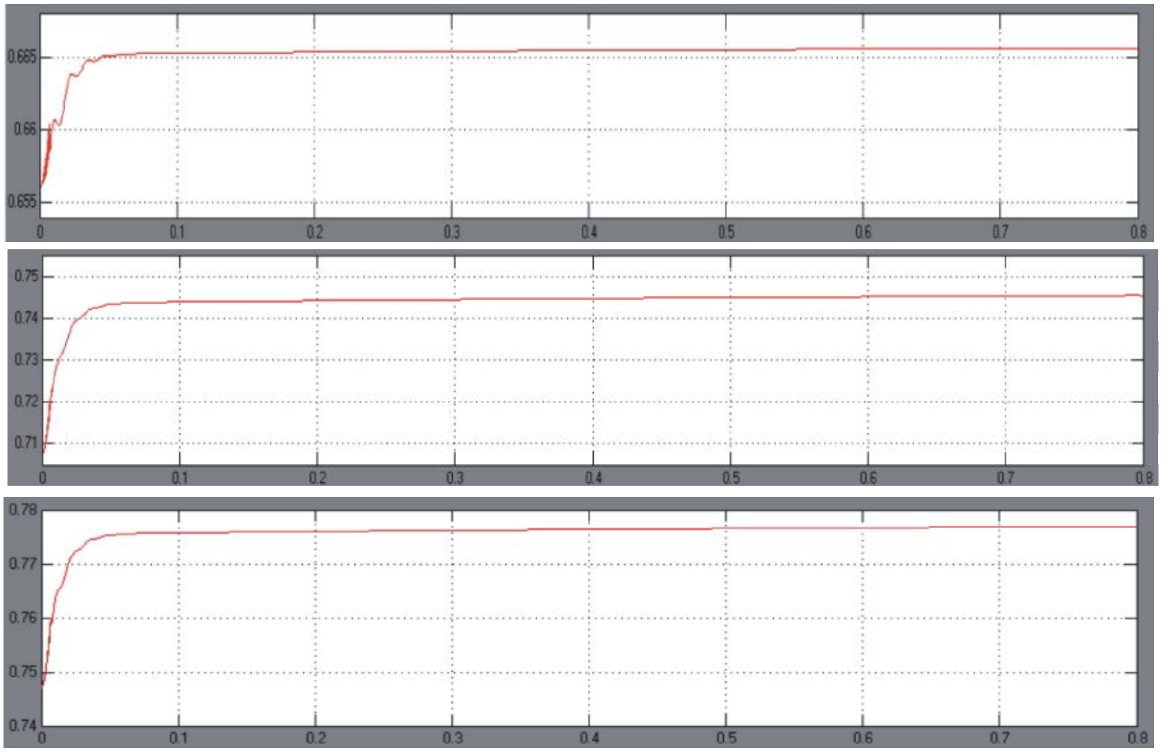


Fig. 6: Voltage waveforms with STATCOM
(i) Voltage at Bus B1
(ii) Voltage at Bus B2
(iii) Voltage at Bus B3

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 2 [16].

## CONCLUSION

In this paper a six-pulse using a three-level voltage-sourced inverter 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 augmentation of voltage regulation in the system and STATCOM is most effective when connected at the Midpoint of a transmission system.

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