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DYNAMIC STUDY OF STATCOM

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ABSTRACT

The electrical power system all over the world tries to provide a safe and reliable electric power to its consumers. But one of the most important problems encountered by the power system is that of power system stability. A power system is said to be stable if it remains in its state of equilibrium even after being subjected to disturbance. Hence, for maintaining power system stability FACTS devices are used. Flexible AC Transmission devices (FACTS) provide reactive power compensation, wave correction and maintain voltage profile of line. They are further of two types: shunt connected and series connected. One such shunt connected device is STATCOM (Static Synchronous Compensator). The STATCOM provides reactive power compensation and maintains line voltage within desired limits and if DC source like battery is used in its VSC it can also exchange real power with line. Hence, it helps in maintaining line stability. This paper deals with the study of STATCOM by using MATLAB/SIMULINK.

General Terms
FACTS, fault detection

Keywords
Flexible AC Transmission System (FACTS), Static Synchronous Compensator (STATCOM), Static VAR Compensator (SVCs), Voltage Source Converter (VSC).

1. INTRODUCTION
In order to improve transient stability of power grids and control power flow through them FACTS devices are used. FACTS devices or Flexible AC Transmission Systems are power electronic based devices which control real and reactive power in the grid and in turn control line voltage and frequency. These FACTS devices can be both shunt and series connected. One such shunt connected device is static synchronous compensator (STATCOM). A STATCOM provides reactive power compensation to the line by regulating its terminal voltage and in turn injecting or withdrawing reactive into or from line. Depending on the system voltage, the STATCOM behaves like a reactive power generator (capacitor) or reactive power sinks (inductor).

A STATCOM is typically made of a voltage source inverter which is on one terminal connected to a DC source and on other terminal connected to AC bus or line. The type of power electronics device used in the voltage source converter (VSC) of STATCOM depends on the power rating of STATCOM. If the power rating of STATCOM is high then GTOs must be used and if the STATCOM has lower power rating IGBT can be used in VSCs.

In this paper a model of GTO based STATCOM which is connected to a transmission line is made using MATLAB/SIMULINK. This model is used to study the dynamic performance of STATCOM.

Since, the use of STATCOM became more and more widespread, many researchers performed various studies on it. In 2006, [1] Presented an analysis on three-phase self excited induction generator (SEIG) with static synchronous compensator (STATCOM) which was current controlled and acted as voltage regulator. During severe load fluctuations the STATCOM which was connected to the induction generator provided fast dynamic response and maintained constant voltage at the terminals of SEIG. The main advantage of STATCOM was that along with maintaining constant voltage at the terminals of SEIG, the voltage provided by STATCOM has lesser harmonics which improves the performance of SEIG. In [2] a model of static synchronous compensator was developed and it was used for studying the performance of STATCOM for power quality analysis. The switching function and control system of STATCOM was also presented.

In this paper a model of GTO based STATCOM which is connected to a transmission line is built using MATLAB/SIMULINK. This model is used to study the dynamic performance of STATCOM.

2. BASIC CONFIGURATION OF STATCOM
The basic structure of STATCOM is made up of a voltage source converter. The converter can be a current source converter but voltage source converter is preferred over the current source converter [3]. The VSC one end is connected to a DC source. If this voltage source is a capacitor then the STATCOM will provide only reactive power compensation. But if the DC source like battery or fuel cell is used then it is possible to provide real as well as reactive power compensation in line using STATCOM. The other terminal of the voltage source converter is connected to the transmission line trough a tie reactance and a coupling transformer. Practically, this tie reactance is provided by leakage reactance

of the coupling transformer itself. The figure below shows the basic configuration of STATCOM.

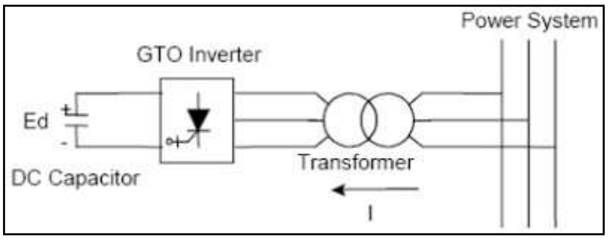

Fig 1: Basic Configuration of STATCOM

3. OPERATION OF STATCOM

The basic operation of STATCOM is explained with the help of fig 2. The frequency at which VSC operates is same as that of system frequency. When the system voltage increases above a certain nominal value then the voltage across the output terminal of STATCOM reduces and reactive power flows from AC bus to STATCOM and reduces line voltage in process. This flow of reactive power continues till the voltage across both line and STATCOM becomes equal. If there is a condition of voltage sag (reduction of line voltage below its nominal value), the voltage across the output terminal of STATCOM is such that the reactive power flows from STATCOM to line and thus increases line voltage upto its nominal value.

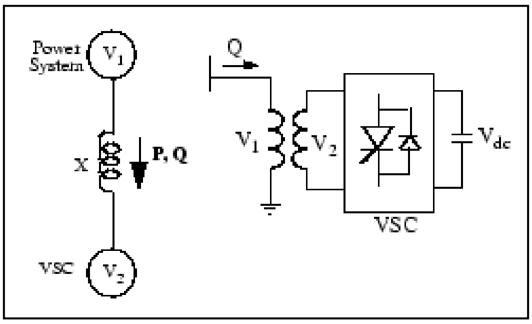

Fig 2: Operating principle of STATCOM

If Q is reactive power which is exchanged between the line and STATCOM, V_1 is the system voltage, X is the tie reactance and V_2 is STATCOM output voltage then,

$$Q = \frac{V1(V1-V2)}{X}$$

In order to synthesize voltage V2 from a DC voltage source force commutated power electronic devices are used in VSC. The transfer of active and reactive power takes place between V_1 and V_2. The inverter used is a GTO based voltage source inverter [4].

4. COMPARISION BETWEEN STATCOM AND SVCs

Static VAR compensators (SVCs) are reactive power sources connected in parallel to transmission line through a bidirectional switch (power electronics switch). Though both provide shunt reactive power compensation still STATCOM is more preferable over SVCs because of following reasons [3]:

- The V/I characteristic of STATCOM is better than SVCs

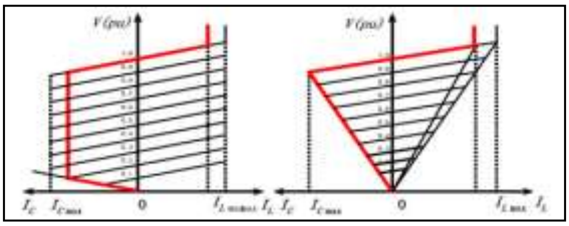

Fig 3: V/I characteristics of STATCOM and SVC

  For very low system voltages STATCOM provides full range compensation current but in case of SVCs the compensation current is directly proportional to the system voltage, so if system voltage reduces then the value of compensation current also reduces.
- The transient stability of STATCOM is better than SVCs due to its ability to maintain full capacitive output current even at low system voltage.
- The response time of STATCOM is better than SVCs. The response time of STATCOM is in the range of 200µs-350µs and that of SVC is in the range of 2.5-5.0ms.
- When STATCOM is connected with dc source like battery or fuel cell instead of capacitor the along with reactive power it can also exchange real power with the line.

5. MODEL AND SIMULATION

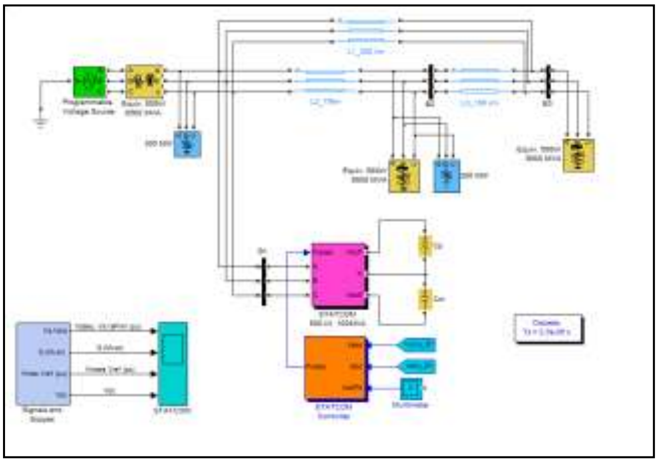

Fig 4: Circuit for studying dynamic model of STATCOM

a) simple *Transmission System with STATCOM*

Figure 4 shows a model of a STATCOM connected to a 500kV power transmission system. This 100MVAR STATCOM regulates the voltage at bus B1. In order to study the dynamic response of the STATCOM the internal voltage of the three phase programmable voltage source block which is connected to bus B1 is varied.

The STATCOM is made up of a three level 48 pulse inverter (VSC). The DC source are two 3000µF capacitors which are series connected. The inverter synthesizes a variable amplitude voltage at frequency 50 Hz from variable DC voltage.

b) 48-Pulse Three-Level Inverter

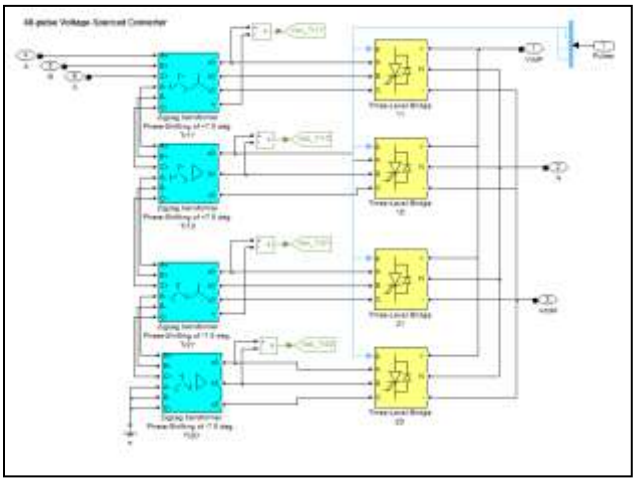

Fig 5: 48-pulse three-level inverter

Figure 5 shows a 48-pulse three level inverter model. It consists of four 3 phase three level inverters which are coupled with four phase shifting transformers introducing a phase shift of ±7.5˚. This transformer arrangement neutralizes all harmonics upto 45^{th} harmonic except for 23^{rd} and 25^{th} harmonics. The 5+12n (5, 17, 29, 41 …) and 7+12n (7, 19, 31, 43…) harmonics are cancelled by star and delta transformer's secondary. There is a 15˚ phase shift between the two groups of transformers (Tr1Y and Tr1D leading by 7.5˚, Tr2Y and Tr2D lagging by 7.5˚) due to this 11+2n (11, 35…) harmonics gets cancelled. The transformers with delta or ungrounded star do not transmit 3n harmonics; hence the harmonics that don't get cancelled are 23^{rd}, 25^{th}, 47^{th} and 49^{th}. Among these harmonics the effect of23rd and 25^{th} harmonics can be minimized by choosing appropriate conduction angle. Hence, only harmonics 47^{th} and 49^{th} harmonics are significant harmonics that are generated from this arrangement. The STATCOM hence generates a step voltage approximating a sine wave [4].

c) STATCOM Control System

Figure 6 shows a model of the control system of a STATCOM. Its function is to vary the DC voltage of the capacitor to enable the inverter to generate an AC voltage which has appropriate amplitude for proper reactive power compensation. Along with this the control system also keeps the AC voltage generated by the inverter in phase with the system voltage at the point of connection of STATCOM.

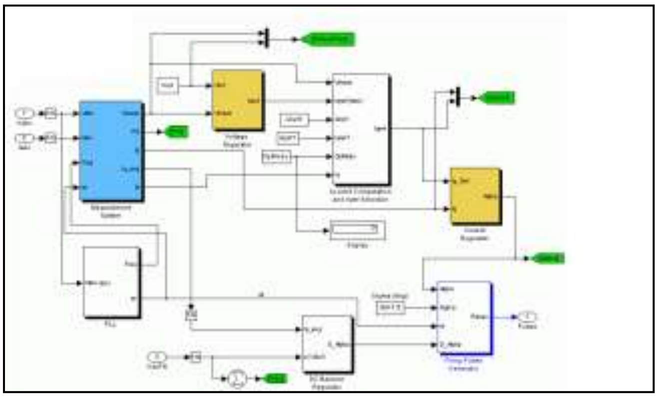

Fig 6: Control circuit of STATCOM

Following modules are used by control system:

i) PLL (Phase Locked Loop): Its main function is to synchronize GTO pulses to the system voltage and thus provide a reference angle to the management system.
ii) Measurement System: It computes the positive sequence components of the voltage and current of STATCOM. This is done using phase- dq transformation and a running window averaging.
iii) Voltage Regulation: This is done using two PI regulators. . In this a reactive current reference (I_{qref}) is computed by voltage reference block (outer loop) from the reference voltage (V_{ref}) and measured voltage (V_{meas}). This reference current (I_{qref}) is used by the current regulator loop. The output of this current controller loop is the angle (α) which is the phase shift of the inverter voltage with respect to the system voltage. The value of α stays close to zero except for short periods of time.
iv) Firing pulse generator: The firing pulse generator generates firing pulses from the output of PLL (ω, t) and the output of current regulator (α) for four inverters.

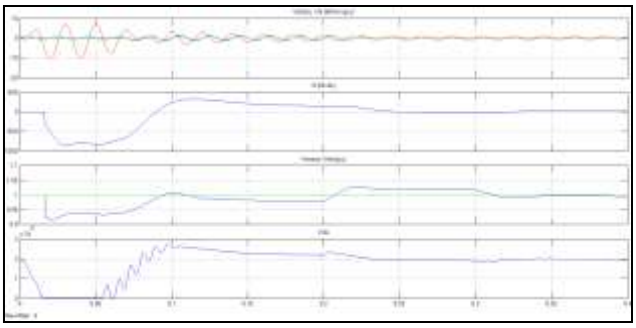

Fig 7: Waveforms Illustrating Dynamic Performance of STATCOM

6. CONCLUSION

In this paper a model of STATCOM and its dynamic performance was studied and it was concluded that:

- The STATCOM made of 48 pulse three level GTO based inverter with the phase shifting transformers was capable of neutralizing the harmonics efficiently and thus can be used as FACTS device that operates at high power rating.

- The simulation verified that the STATCOM has good dynamic response and is capable of regulating the transmission system voltage efficiently.

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