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MULTILEVEL INVERTER BASED GRID CONNECTED STATCOM

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Abstract- Modern day power systems, power electronic devices are playing vital role in every aspect of the power system network. Among various devices multi-level inverters are the most efficient devices due to their Simple circuit configuration, reliability and cost effective implementation. Application of multi-level inverters along with STATCOM using SPWM (Sinusoidal Pulse Width Modulation) technique improves the operation & utilization of power system. Because STATCOM injects reactive component into the power system during large disturbances. This paper deals with multilevel converter based STATCOM and the results are studied through MATLAB Simulink.

Keywords*- Multi level converters, FACTS, STATCOM, Voltage source converter.*

I. INTRODUCTION

In recent years, major transformations have been introduced into the structure of electrical power utilities to improve efficiency in the operation of the power system networks by deregulating the industries and opening it to their private competitors. This global trend and similar structural changes have occurred elsewhere in other industries, i.e., in airline transportation and telecommunications industries. The net effect of such adjustments will mean that the generation, transmission and distribution systems must now adapt to a new set of rules dictated by open markets. In particular for the transmission sector of power utilities, this adaptation may require the construction or modification of inter-connections between regions and countries. Furthermore, the adaptation to new generation patterns will also necessitate changes and will require increased flexibility and availability of the transmission system. Adding to these problems is the growing environmental concern and the constraints upon the rights-ofway for new installations and facilities. Yet additional demands are continually being made upon utilities to supply increased loads, to improve reliability, and to deliver energy at the lowest possible cost and with improved power quality. The power industry has responded to these challenges with the power-electronics-based technology of flexible AC transmission systems (FACTS). This term covers a whole family of power electronic controllers, some of which may have achieved maturity within the industry, while some others are as yet in the design stage.

Among FACTS controllers, the shunt controllers have shown feasibility in term of cost effectiveness in a wide range of problem-solving from transmission to distribution levels. the shunt controller can improve transient stability and can damp power oscillation during a post-fault event. Using a high-speed power converter, the shunt controller can further alleviate or even cancel the flicker problem caused by electrical arc furnaces. In principle, all shunt-type controllers inject additional current into the system at the point of common coupling (PCC). An impedance of the shunt controller, which is connected to the line voltage, causes a variable current flow, and hence represents an injection of current into the line. As long as the injected current is in phase quadrature with the line voltage, the shunt controller only supplies or consumes variable reactive power.

Employing turn-off-capability semiconductor devices, switching power converters have been able to operate at higher switching frequencies and to provide a faster response. This makes the voltage-source converter (VSC) an important part in the FACTS controllers [G2]. The STATCOM is the first power-converter-based shunt-connected controller. The concept of STATCOM was disclosed by Gyugyi in 1976 [G3]. Instead of directly deriving reactive power from the energy-storage components, the STATCOM basically circulates power with the connected network. The reactive components used in the STATCOM, therefore, can be much smaller than those in the SVC. The Multilevel Converter-based STATCOM, however, challenges researchers to improve its dynamic responses and to balance its excessive number of DC capacitor voltages. To date, several papers have discussed the configurations and control strategies for the reactive power compensation systems that utilize Multilevel Converter s [1-7]. Based on these previous works, an accurate model and an effective control technique associated with the simple DC capacitor balancing strategy are elements important to achieving a high-performance, stable, cost-effective Multilevel Converter -based STATCOM.

II. OPERATING PRINCIPLE OF THE STATCOM

The STATCOM is the solid-state-based power converter version of the SVC. The concept of the STATCOM was proposed by Gyugyi in 1976.

Operating as a shunt-connected SVC, its capacitive or inductive output currents can be controlled independently from its connected AC bus voltage. Because of the fast-switching characteristic of power converters, the STATCOM provides much faster response as compared to the SVC. In addition, in the event of a rapid change in system voltage, the capacitor voltage does not change instantaneously; therefore, the STATCOM effectively reacts for the desired responses. For example, if the system voltage drops for any reason, there is a tendency for the STATCOM to inject capacitive power to support the dipped voltages.

Theoretically, the power converter employed in the STATCOM can be either a VSC or a current-source converter (CSC). In practice, however, the VSC is preferred because of the bidirectional voltage-blocking capability required by the power semiconductor devices used in CSCs. To achieve this kind switch characteristic, an additional diode must be connected in series with a conventional semiconductor switch, or else the physical structure of the semiconductor must be modified. Both of these alternatives increase the conduction losses and total system cost.

In general, a CSC derives its terminal power from a current source, i.e., a reactor. In comparison, a charged reactor is much lossier than a charged capacitor. Moreover, the VSC requires a current-source filter at its AC terminals, which is naturally provided by the coupling transformer leakage inductance, while additional capacitor banks are needed at the AC terminals of the CSC.

In conclusion, the VSCs can operate with higher efficiency than the CSCs do in high-power applications. A suitable VSC is selected based on the following considerations: the voltage rating of the power network, the current harmonic requirement, the control system complexity, etc.

Basically, the STATCOM system is comprised of three main parts: a VSC, a set of coupling reactors or a step-up transformer, and a controller. In a very-high-voltage system, the leakage inductances of the step-up power transformers can function as coupling reactors. The main purpose of the coupling inductors is to filter out the current harmonic components that are generated mainly by the pulsating output voltage of the power converters. The STATCOM is connected to the power networks at a PCC, where the voltage-quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches of the power converter accordingly. The single line diagram of the STATCOM system is illustrated in Figure 1. In general, the VSC is represented by an ideal voltage source associated with internal loss connected to the AC power via coupling reactors.

In principal, the exchange of real power and reactive power between the STATCOM and the power system can be controlled by adjusting the amplitude and phase of the converter output voltage. In the case of an ideal lossless power converter, the output voltage of the converter is controlled to be in phase with that of the power system. In this case, there is no real power circulated in the STATCOM; therefore, a real power source is not needed. To operate the STATCOM in capacitive mode or var generation, +Q, the magnitude of the converter output voltage is controlled to be greater than the voltage at the PCC. In contrast, the magnitude of the output voltage of the converter is controlled to be less than that of the power system at the PCC on order to absorb reactive power or to operate the STATCOM in inductive mode, -Q. However, in practice, the converter is associated with internal losses caused by non-ideal power semiconductor devices and passive components. As a result, without any proper controls, the capacitor voltage will be discharged to compensate these losses, and will continuously decrease in magnitude. To regulate the capacitor voltage, a small phase shift δ is introduced between the converter voltage and the power system voltage. A small lag of the converter voltage with respect to the voltage at the PCC causes real power to flow from the power system to the STATCOM, while the real power is transferred from the STATCOM to the power system by controlling the converter voltage so that it leads the voltage at the PCC.

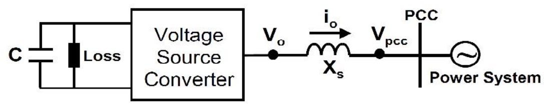

Figure 1. Single-line diagram of the voltage-source converter-based STATCOM.

III. MULTILEVEL INVERTER STRUCTURES

A voltage level of three is considered to be the smallest number in multilevel converter topologies. Due to the bi-directional switches, the multilevel VSC can work in both rectifier and inverter modes. This is why most of the time it is referred to as a converter instead of an inverter in this dissertation. A multilevel converter can switch either its input or output nodes (or both) between multiple (more than two) levels of voltage or current. As the number of levels reaches infinity, the output THD approaches zero. The number of the achievable voltage levels, however, is limited by voltage-imbalance problems, voltage clamping requirements, circuit layout and packaging constraints complexity of the controller, and, of course, capital and maintenance costs.

Three different major multilevel converter structures have been applied in industrial applications: cascaded H-bridges converter with separate dc sources, diode clamped, and flying capacitors. The multilevel inverter structures are the main focus of discussion in this chapter; however, the illustrated structures can be implemented for rectifying operation as well. Although each type of multilevel converters share the advantages of multilevel voltage source inverters, they may be suitable for specific application due to their structures and drawbacks. Operation and structure of some important type of multilevel converters are discussed in the following sections.

In a multilevel VSI, the dc-link voltage Vdc is obtained from any equipment which can yield stable dc source. Series connected capacitors constitute energy tank for the inverter providing some nodes to which multilevel inverter can be connected. Primarily, the series connected capacitors will be assumed to be any voltage sources of the same value. Each capacitor voltage Vc is given by Vc=Vdc/ (n-1), where n denotes the number of level. Fig. 2 shows a schematic diagram of one phase leg of inverters with different number of levels, for which the action of the power semiconductors is represented by an ideal switch with several positions. A two-level inverter generates an output voltage with two values (levels) with respect to the negative terminal of the capacitor, while the three-level inverter generates three voltages, and so on.

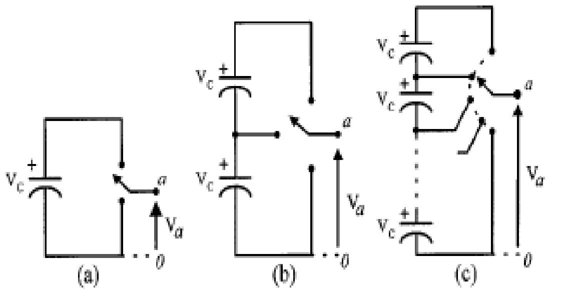

Fig. 2 One phase leg of an inverter with (a) two levels, (b) three levels, and (c) n levels.

IV. SIMULATION RESULTS

Simulation results for the multilevel inverter based statcom are presented in this section. Multilevel inverter based statcom is simulated using MATLAB/SIMULINK. Grid connected load with STATCOM support is considered for case study. Fig 3 show the grid voltage. Load on the system is applied at 0.3 sec and the STATCOM support is also there for the systems from 0.3 sec, so the load current is continuous but less current is drawn from the grid and the remaining current is supported by the STATCOM. At t=0.7 seconds, STATCOM is removed so the total current is drawn from the grid itself. Sumultaion results for grid current ,STATCOM current and load current are shown in fig 3, fig 4, and fig 5 respectively.

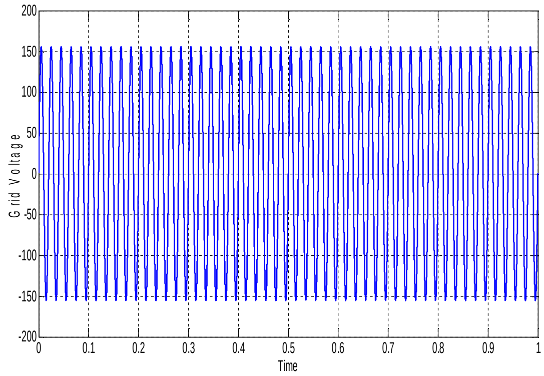

Fig 3. Grid voltage of the STATCOM supported grid

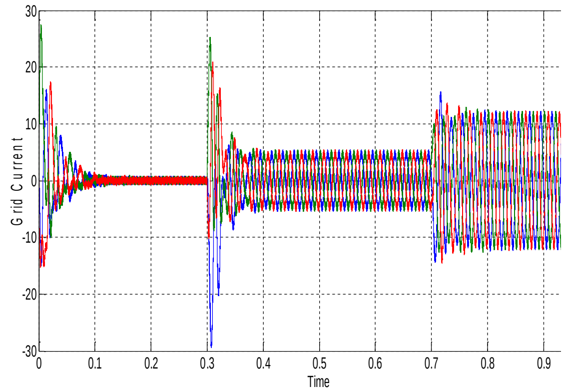

Fig 3. Grid Current of the STATCOM supported grid

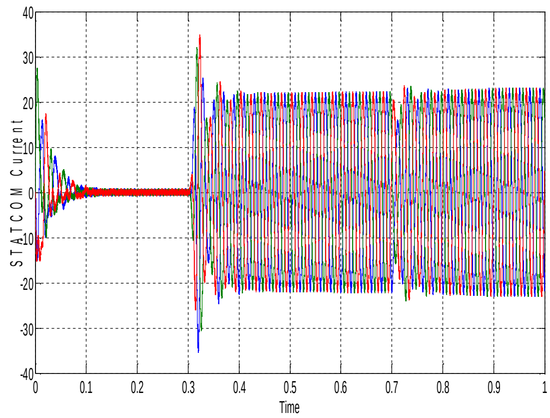

Fig 4. Current injected from the STATCOM

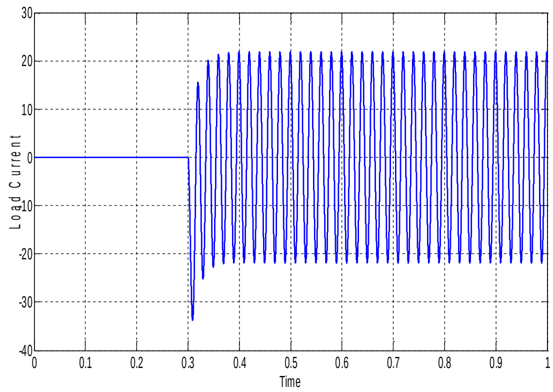

Fig 5. Load current when the load is switched on at t=0.3s.

V. CONCLUSIONS:

Among FACTS controllers, the shunt controllers have shown feasibility in terms of cost effectiveness in a wide range of problem-solving abilities from transmission to distribution levels. The STATCOM is the first power-converter based shunt-connected controller. among the mature STATCOM topologies, the multilevel converter based STATCOM is the most promising alternative for the STATCOM application. So the simulation results in this paper presents the performance of the STATCOM in grid supporting application.

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