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Research Paper

Modelling of Statcom Utilising Cascaded Eleven Level Inverter (H Bridge)

Engineering

KEYWORDS : Static synchronous compensator, Cascaded multilevel inverter (H-bridge), ABC coordinates

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ABSTRACT

This paper is dedicated to a comprehensive study of static synchronous compensator (STATCOM) systems utilizing cascaded-multilevel inverters. Among flexible AC transmission system (FACTS) controllers, the STATCOM have shown feasibility in terms of cost effectiveness in a wide range of problem-solving abilities from transmission to distribution levels. A cascade multilevel inverter is a power electronic device built to synthesize a desired AC voltage from several levels of DC voltages. A method is presented showing that a cascade multilevel inverter can be implemented using only a single DC power source and capacitors. To control the reactive power instantaneously, this system is modelled using the ABC transform which calculates the instantaneous reactive power. The simulation result of MATLAB/Simulink software indicates the superior performance of the proposed control system, as well as the precision of the proposed models.

1. INTRODUCTION

Among flexible AC transmission system (FACTS) controllers, the STATCOM have shown feasibility in terms of cost effectiveness in a wide range of problem-solving abilities from transmission to distribution levels. A cascade multilevel inverter is a power electronic device built to synthesize a desired AC voltage from several levels of DC voltages. A cascade multilevel inverter can be implemented using only a single DC power source and capacitors. To operate a cascade multilevel inverter using a single DC source, it is proposed to use capacitors as the DC sources. A standard cascade multilevel inverter requires 's' DC sources for 2s+1 level. To be able to operate in a high-voltage application, a large number of DC capacitors are utilized in a cascaded multilevel inverter-based STATCOM. To obtain a low distortion output voltage or a nearly sinusoidal output waveform, a triggering signal should be generated to control the switching frequency of each power semiconductor switch.

2. OBJECTIVE

The objective is to come out with a simulation model of STATCOM based cascaded eleven inverter and analyzes its operation.

3. COMPARATIVE ANALYSIS OF CASCADED MULTILEVEL INVERTERS

Multilevel inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages with stepped waveforms. By increasing the number of levels in the inverter, the output voltages have more steps generating a staircase waveform, which has a reduced harmonic distortion. However, a high number of levels increases the control complexity and introduces voltage imbalance problems. For example, 11-level cascaded H-bridge inverters will have 5 SDCSs and 5 full bridges.

The most attractive features of Cascaded Multilevel Inverters are as follows:

- They can operate with a lower switching frequency.
- They draw input current with very low distortion.
- They can generate output voltages with extremely low distortion and lower dv/dt.
- They generate smaller common-mode (CM) voltage, thus reducing the stress in the motor bearings. In addition, using sophisticated modulation methods, CM voltages can be eliminated.

4. POWER CIRCUIT AND SYSTEM MODELLING

4.1 Power Circuit and Operation Principle

An eleven level, three-phase STATCOM based on the cascading configuration is illustrated in Figure 1.

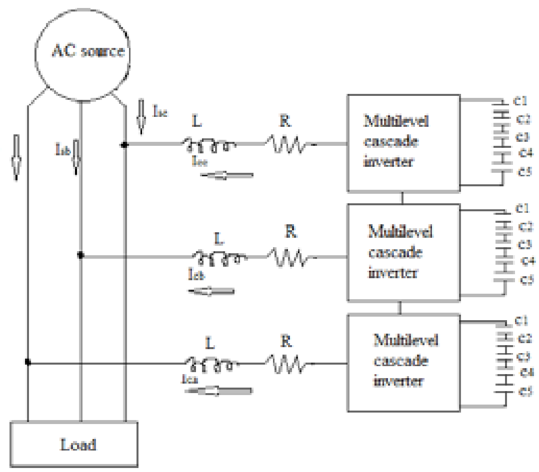

Figure 1 Structure of the STATCOM with cascade multilevel inverter

Figure 1 illustrates the connection diagram for a star connection 11-level inverter using the cascade voltage source H-bridge inverters. Each HBI can generate three level output, $+V_{dc}$, o and $-V_{dc}$. When the inverter output voltage is higher than the ac system voltage, leading reactive current is drawn from the system (vars are generated). When the inverter output voltage is lower than the ac system voltage, the lagging reactive current is drawn from the system (vars are absorbed). When the inverter output voltage is equal to the AC system voltage reactive power exchange is zero. The AC voltage controlled STATCOM can control the amplitude of AC voltage by causing a small amount of active power to power flow into or out of the STATCOM.

4.2 Control of Reactive Power

It is well known that the amount and type (capacitive or inductive) of reactive power exchange between the STATCOM and the system can be adjusted by controlling the magnitude of STATCOM output voltage with respect to that of system voltage. Figure 2 shows simulated circuit of STATCOM with 11-level cascaded multilevel inverter

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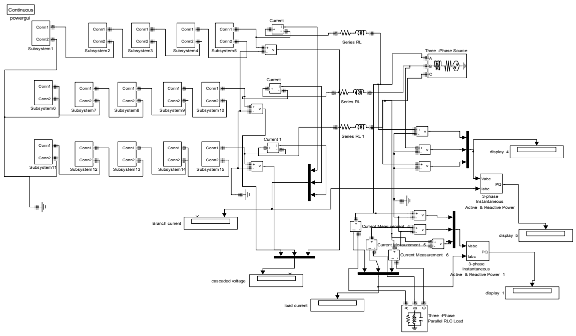


Figure 2 Simulated circuit of the STATCOM with 11-level cascaded multilevel inverter

The reactive power supplied by the STATCOM is given by equation (1),

$$Q = V_{statcom} - V_s \quad (1)$$

Where, $V_{statcom}$ and V_s are the magnitudes of STATCOM output voltage and system voltage respectively and X is the equivalent reactance between STATCOM and the system. When Q is positive, the STATCOM supplies reactive power to the system. Otherwise, the STATCOM absorbs reactive power from the system.

The phase output voltage is synthesized by the sum of individual inverter outputs,

i.e. Vca= Vca1+Vca2+Vca3+............. +Vcan

Therefore, the phase voltage for 11-level cascaded inverter is,

Vca=Vca1+Vca2+Vca3+Vca4+Vca5

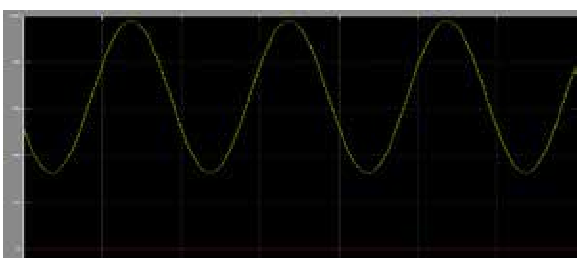
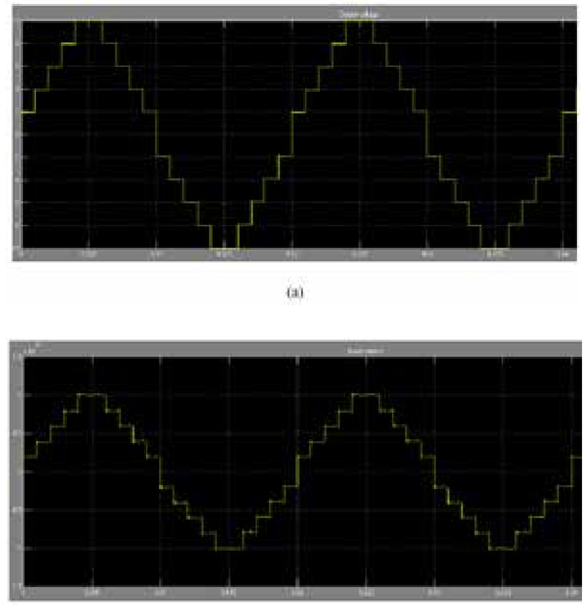


Figure 3 Reactive power in 3-phase cascaded eleven level inverter based STATCOM

Figure 3 shows reactive power of STATCOM with 11 level cascaded multilevel inverter. Since the modulating signals are the same for the inverters in the system, the fundamental component of the STATCOM output voltage is N time of that of each inverter, provided that the voltage across the DC capacitor of each inverter is the same. As a result, the STATCOM output voltage can be controlled by the Modulation index due to its ability to control the output voltage by the modulation index; the proposed STATCOM has extreme fast dynamic response to system reactive power demand.

SIMULATION RESULT



(a)

(b)

Figure 4 Simulated Output phase waveforms of 11-level cascaded inverter with separate DC sources (a) voltage (b) current (when load is RL)

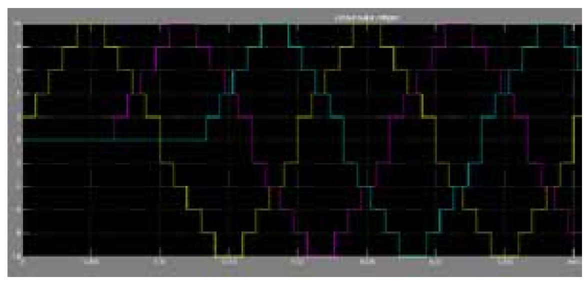


Figure 5 Simulated 3-phase Output voltage waveforms of 11-level cascaded inverter with separate DC sources

Figure 5 shows the cascaded eleven level inverter output phase voltage waveform. It can be seen that the sinusoidal waveform and the eleven level cascaded inverter output waveform both are approximately same. But the square wave output has a high harmonic content, not suitable for certain AC loads such as motors or transformers.

6 Conclusion

With its modularized structure, the Cascaded Multilevel Inverter can flexibly expand the output power capability and is favourable to manufacturing. Control complexity of the Cascaded Multilevel Inverter is, however, directly proportional to the number of H-bridge inverters. In the STATCOM application, the AC voltage of each H-bridge converter is derived from its DC capacitor voltage or supply voltage, which needs to be individually regulated. As the number of voltage levels increases, the voltage-imbalance problem becomes more of a concern.

To achieve as stable a system as possible, a well-defined model and an effective DC-link-balancing method are necessary. The cascaded seven-level, nine-level inverters have been used as the studied system. And, the cascaded eleven level inverter based STATCOM is designed according to the simplified model in abc coordinates. The simulation results show superior performances of the designed abc coordinates inverter based STATCOM. The STATCOM has the great advantage of a fewer number of devices. The VSI is extremely fast in response to reactive power change.

The simulation of the STATCOM is performed in the Simulink environment and the results are presented.

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