# Voltage Compensation for A 11 kV Distribution System using Multilevel Inverter

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***Abstract*-This paper presents a Distribution Static Compensator (DSTATCOM) with a sinusoidal pulse width modulated (SPWM)Cascaded H Bridge (CHB) multilevel inverter for shunt compensation of distribution system. The advantages of DSTATCOM are power factor improvement, voltage regulation and harmonic mitigation in distribution line and load balancing. CHB inverters are used widely because of their simplicity, modularity and reduced switching losses. Here a five level cascaded H bridge based DSTATCOM is considered for the voltage sag compensation of an 11 kV distribution system. The software used is MATLAB. The performance of multilevel inverter is investigated and Total Harmonic Distortion (THD) is noticed.**

***Keywords-DSTATCOM; CHB multilevel inverter; Power Quality; Level Shifted Pulse Width Modulation (LSPWM); Phase Shifted Pulse Width Modulation (PSPWM)***

## I. INTRODUCTION

In modern electrical power systems, electricity is produced at generating stations, transmitted through a high voltage network, and finally distributed to consumers. Due to the rapid increase in power demand, electric power systems have developed extensively, resulting in today's power industry probably being the largest and most complex industry in the world. A power system should provide reliable and uninterrupted services to its customers, especially distribution systems. Distribution systems have numerous nonlinear loads, which significantly affect the quality of power. Any power problem manifested in voltage, current, or frequency deviation that results in failure or disoperation of customer equipment is a power quality (PQ) problem. There is a wide variety of power quality disturbances which affect the performance of customer equipment. Some of them are transients, voltage fluctuations, harmonics, voltage unbalance, noise, dc offsets etc. Voltage sag is defined as a short reduction in voltage magnitude for duration of time, and is the most important and commonly occurring power quality issue. Various methods have been applied to reduce or mitigate the PQ problems. The conventional methods are by using capacitor banks, introduction of new parallel feeders and by installing Uninterrupted Power Supplies (UPS). Techniques using fast controlled force commutated power electronics are even more effective. PQ compensators are used to mitigate the adverse impacts on the power quality. They are classified as shunt compensation devices and series compensation devices.

DSTATCOM is a shunt type compensating device connected in distribution system. By suitably adjusting the phase and magnitude of the DSTATCOM output voltage, effective control of active and reactive power exchanges between the DSTATCOM and the ac system is possible.

A multilevel inverter is to synthesis a sinusoidal voltage from several levels of voltages, typically obtained from capacitor voltage sources. There are different types of multilevel inverters: diode-clamp, flying capacitor, and cascaded H Bridge (CHB) [3-6]. Out of these CHB are commonly used because of their wide range of advantages such as simplicity, modularity, increased number of voltage levels, low switching losses, higher order harmonic elimination etc. In this paper for voltage sag compensation five level cascaded H Bridge topology is used. It is found that compensation can be effectively done by this topology with suitable control scheme.

## II. SYSTEM CONFIGURATION

A DSTATCOM consist of two level Voltage Source Converter (VSC), a dc energy storage device, and a coupling transformer connected in shunt to the distribution network through a coupling transformer. Fig. 1 shows the schematic diagram of DSTATCOM.

DSTATCOM is connected to the power system at the point of common connection (PCC), using transformer leakage reactance which gives active and reactive power exchange between the power system and the DSTATCOM. In ideal case the output voltage of the VSC is in phase with source voltage.

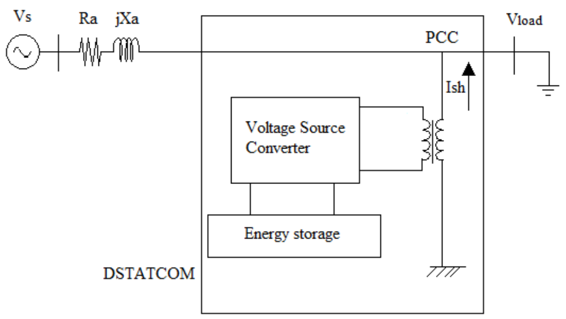


Fig. 1. Basic structure of DSTATCOM

The ac terminal of the VSC is connected toPCC. And the dc side of the converter is connected to a dc capacitor.

If the output voltage of the VSC is equal to the ac terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the system voltage, the DSTATCOM is in the capacitive mode of operation. Similarly if the output voltage is less than the system voltage, the DSTATCOM is in the inductive mode of operation.

The complex power injection of the DSTATCOM can be expressed as,

$$S_{sh}=V_{load}I_{sh} \qquad (1)$$

The value of $I_{sh}$ can be controlled by adjusting the output voltage of the converter.

## III. PROPOSED DSTATCOM TOPOLOGY

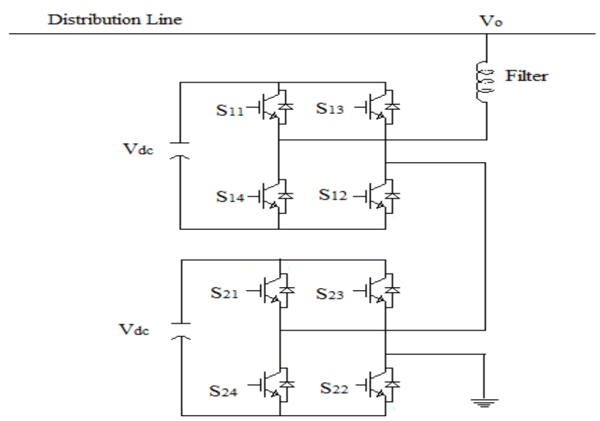


Fig. 2. Single phase, five level H bridge inverter based DSTATCOM

The number of output voltage levels of CHB is given by 2n+1 and voltage step of each level is given by $V_{dc}/2n$, where n is the number of H bridges connected in series [2]. Table 1 shows the switching states of the five level inverter

| Switches Turn on | Voltage Level($V_0$) |
|---|---|
| $S_{11}$,$S_{12}$,$S_{24}$,$S_{22}$ | $V_{dc}$ |
| $S_{11}$,$S_{12}$,$S_{21}$,$S_{22}$ | $2V_{dc}$ |
| $S_{14}$,$S_{12}$,$S_{24}$,$S_{22}$ | 0 |
| $S_{11}$,$S_{13}$,$S_{21}$,$S_{23}$ | 0 |
| $S_{13}$,$S_{14}$,$S_{21}$,$S_{23}$ | $-V_{dc}$ |
| $S_{13}$,$S_{14}$,$S_{23}$,$S_{24}$ | $-2V_{dc}$ |

Table 1. Switching table for five level CHB inverter

Cascaded multilevel inverter based DSTATCOM is connected in the distribution network at the PCC through filter inductance. The gating signals for the inverter switches are provided using sinusoidal PWM technique, where a sinusoidal reference is compared with triangular carrier waveform. The reference is generated in according to the output of PI controller.

## IV. CONTROL SCHEME

The control system measures the rms voltage at the load point. The controller input is an error signal obtained from the reference voltage which is the normal system voltage (430 V) and the rms terminal voltage measured. Such error is processed by a PI controller [8]. Fig. 3 shows the PI control for reactive power compensation.

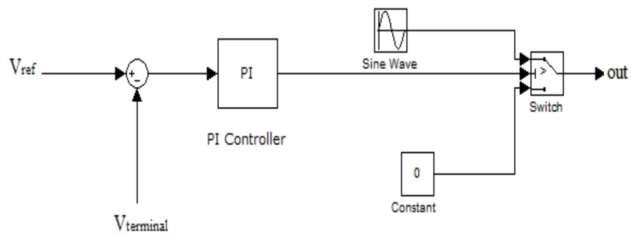


Fig. 3. PI control for reactive power compensation

When an error occurs, the output is the sine wave, which is provided to the PWM signal generators. This sine wave in comparisons with the carrier wave generates the switching signals for the inverter. Inverter provides the necessary compensation and the error is driven to zero i.e. the load rms voltage is brought back to the reference voltage

## V. PWM TECHNIQUE FOR CHB INVERTER

The CHB inverter switching strategy is based on Level shifted carrier PWM (LSCPWM)technique [10]. This is a type of sinusoidal PWM method.

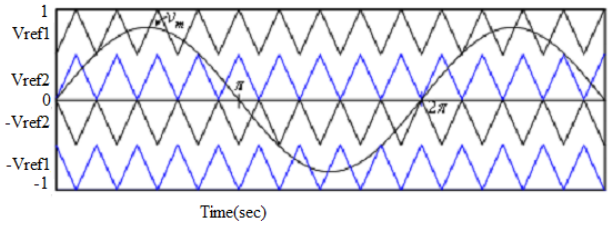

Fig. 4. Level shifted carrier PWM

In level shifted carrier PWM (LSCPWM) a carrier level shift of 1/m for cascaded inverter is introduced across the cells to generate the stepped multilevel output waveform with lower distortion, where m is the number of levels [9].

## VI. SIMULATION AND EXPERIMENTAL RESULTS

The DSTATCOM model is established based on Matlab/Simulink. Simulation is carried out for without DSTATCOM and with five level CHB inverter based DSTATCOM. The system parameters are as following: source voltage of 11kV, 50 Hz AC supply, DC voltage source of 215 V, source resistance of 0.8929 ohm and inductance of 16.58 mH, load resistance of 50 ohm and inductance of 10 mH. Fig. 5 shows the Matlab/Simulink power circuit model of DSTATCOM

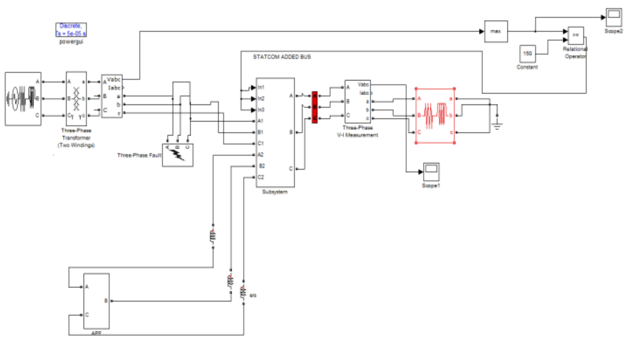
Fig. 5. Simulink model of DSTATCOM

For the voltage compensation five level H bridge inverter based DSTATCOM is used. For simulation purpose a three phase fault is created at 0.2 sec and clear at 0.4 sec with simulation run time 1 sec. The various simulation results of the voltage sag mitigation using five level H Bridge based DSTATCOM are shown below.

Fig. 6 shows the phase A voltage of five level output of level shifted carrier PWM inverter

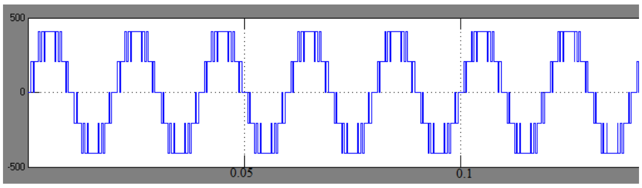

Fig. 6. Five level LSCPWM output

Fig. 7 shows the three phase load voltage and current respectively without DSTATCOM

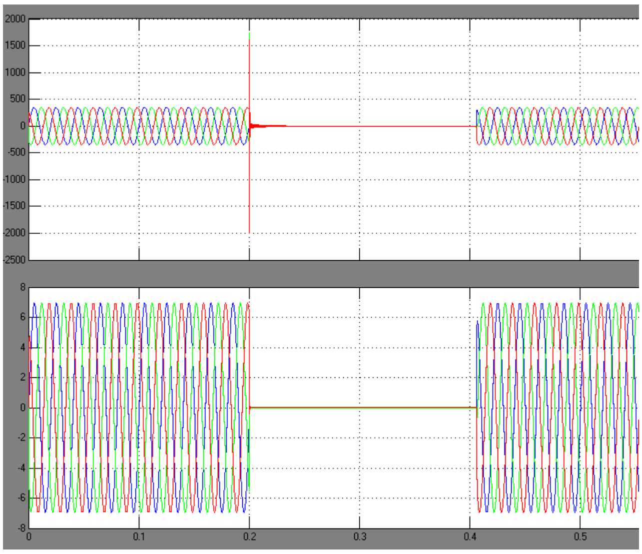

Fig. 7. Load voltage and load current without STATCOM

Fig. 8 shows the three phase load voltage and current respectively with DSTATCOM. It is seen that between the transition period of 0.2 sec and 0.4 sec the DSTATCOM inject the required current.

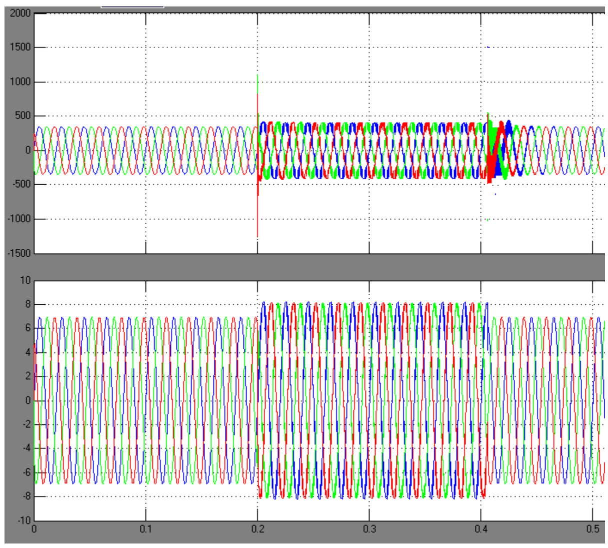

Fig. 8. Load voltage and load current with DSTATCOM

The use of five level cascaded H bridge inverter based DSTATCOM gives better results in terms of THD i.e. reduction in harmonics. The THD of the system is 2.63%

## VII. CONCLUSION

A five level CHB inverter based DSTATCOM has been presented for shunt compensation of an 11 kV distribution system.This type of arrangements has been widely used for PQ applications. A CHB inverter has the advantages of low harmonic distortion, reduced number of switches, suppression of switching losses etc.Simulink based model is developed for the proposed topology and results are obtained. It is observed that the DSTATCOM is capable of supplying the reactive power demanded by the load during any operating conditions. It is found to be more effective than the conventional inverter with lower harmonics.

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