Improvement of Power Loss in High Voltage Converters by Hybrid Multilevel H-Bridge Converters

R. Pramod[1] | Ms. A. Tejasri[2]

[1]PG Scholar, Department of EEE, Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.
[2]Assistant Professor, Department of EEE, Godavari Institute of Engineering and Technology, Rajahmundry, Andhra Pradesh, India.

ABSTRACT

The Multilevel converter‖ has drawn tremendous interest in the power industry. The general structure of the multilevel converter is to synthesize a sinusoidal voltage from several levels of voltages, Multilevel voltage source converters are emerging as a new breed of power converter options for high power applications, These converter topologies can generate high-quality voltage waveforms with power semiconductor switches operating at a frequency near the fundamental. Among the available multilevel converter topologies, the cascaded multilevel converter constitutes a promising alternative, providing a modular design that can be extended to allow a transformer less connection. A new control strategy is proposed in this paper with focus on dc voltage regulation. Clustered balancing control is realized by injecting a zero-sequence current to the delta-loop, while individual voltage control is achieved by adjusting the fundamental content of ac quasi-square-waveform voltage of high-voltage converter.

KEYWORDS: *Cascaded H-Bridge, DC Voltage Control, multilevel Inverter, SSTATCOM.*

I. Introduction

Modern power systems are of complex networks, where hundreds of generating stations and thousands of load centers are interconnected through long power transmission and distribution networks. Even though the power generation is fairly reliable, the quality of power is not always so reliable. Power distribution system should provide with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency to their customers. PS especially distribution systems, have numerous non linear loads, which significantly affect the quality of power. Apart from non linear loads, events like capacitor switching, motor starting and unusual faults could also inflict power quality (PQ) problems. PQ problem is defined as any manifested problem in voltage I current or leading to frequency deviations that result in failure or mal operation of customer equipment. Voltage sags and swells are among the many PQ problems the industrial processes have to face. Voltage sags are more severe. During the past few decades, power industries have proved that the adverse impacts on the PQ can be mitigated or avoided by conventional means, and that techniques using fast controlled force commutated power electronics (PE) are even more effective. PQ compensators can be categorized into two main types. One is shunt connected compensation device that effectively eliminates harmonics. The other is the series connected device, which has an edge over the shunt type for correcting the distorted system side voltages and voltage sags caused by power transmission system faults.

II. Literature Survey

Cascaded H-bridge converter with equal DC voltage has been widely used for STATCOM application because of natural modular and high-quality output spectrum. Compared with diode-clamped converter and flying capacitor converter, cascaded single-phase H-bridge converter saves a large amount of clamped diodes and flying capacitors. However, further improvement of power efficiency and waveform quality is expected of cascade H-bridge topology in high power application. Traditionally, low-distorted AC voltage waveform is achieved by either increasing switching frequency or increasing the cascaded number of modules, which bring high power loss or high cost to the STATCOM system. Fortunately, hybrid multilevel technology provides a good trade off between waveform quality and switching loss. The important advantages of hybrid multilevel converters are as follows: increasing voltage levels of output waveform, improving AC current quality, reducing switching frequency resulting in low switching loss, as well as enhancing converter efficiency.

As the concept of “hybrid multilevel” was proposed in aliterature, great attentions have been paid to this field. In order to achieve hybrid multilevel, many approaches have been published in many literatures. A hybrid topology with the series connection of three-phase full-bridge converter (two-or three-level) and single-phase H-bridge converter is adopted by a literature. This topology effectively produces higher voltage levels compared with traditional ones with the same number of switches, but it is companied by a problem of DC voltage control. One popular method for capacitor voltage control is selecting switching states redundancy, which introducing another problem of uncertain switching frequency for relevant devices. To avoid the issue of DC voltage control, DC link of the hybrid topology is connected directly to expensive DC supplies such as battery, fuel cell and rectifier. In, three-phase three-level converter is fed by rectifiers while the H-bridge converter uses a capacitor as a replacement of DC source for cost saving. Capacitor voltage and NPC voltage is regulated by adjusting common mode voltage. This control algorithm requires a large amount of real-time online calculation, which brings difficulty for STATCOM application. In, all the DC-link voltages are controlled purely by control algorithm. Reactive-power regulation is realized by adjusting DC voltages. However, this control method is based on steady state model and the dynamic performance is not discussed. Additionally, the capability of compensating unbalanced load is not mentioned either.

Moreover, hybrid multilevel topology based on cascaded single-phase H-bridge converter with unequal DC voltage is considered by some literatures. Literatures describe a motor drive system based on hybrid multilevel H-bridge converters with unequal DC voltage supplies. The mentioned control method is not suitable for STATCOM system because the DC sources are replaced by capacitors in STATCOM system.

K.A Corzine. and Y.L Familiant, have presented a general structure for cascaded power converters in which any number of H-bridge cells having any number of voltage levels are series connected to form an inverter phase leg. Equations are introduced for determining an optimal voltage ratio of dc voltages for the H-bridge cells which will maximize the number of voltage levels obtainable resulting in high power quality. Special cases of the generalized inverter are presented including novel 11-level and 15-level inverters. Laboratory measurements demonstrate the proposed inverter performance.

J.S.Lai. and F.Z.Peng presents an investigation of five-Level Cascaded H - bridge (CHB) Inverter as Distribution Static Compensator (DSTATCOM) in Power System (PS) for compensation of reactive power and harmonics. The advantages of CHB inverter are low harmonic distortion, reduced number of switches and suppression of switching losses. The DST ATCOM helps to improve the power factor and eliminate the Total Harmonics Distortion (THD) drawn from a Non-Liner Diode Rectifier Load (NLDRL).

T.A.Maynard. M.Fadel and N.Aouda uses a standard three-leg inverter (one leg for each phase) and an H-bridge in series with each inverter leg which uses a capacitor as the dc power source. The performance of the proposed DSTATCOM is validated through simulation using MATLAB software with its Simulink and Power system block set tools and also the performance of the system without DSTATCOM and with DSTATCOM is evaluated.

J.Rodriguez. Jih-sheng Lai, and F Zhengpeng, presents the most important topologies like diode-clamped inverter (neutral-point clamped), capacitor-clamped (flying capacitor), and cascaded multicell with separate DC sources. Emerging topologies like asymmetric hybrid cells and soft-switched multilevel inverters are also discussed. RoozbehNaderi, and Abdolrezarahmati, presents an investigation of seven-Level Cascaded H - bridge (CHB) Inverter as Distribution Static Compensator (DSTATCOM) in Power System (PS) for compensation of reactive power and harmonics. The advantages of CHB inverter are low harmonic distortion, reduced number of switches and suppression of switching losses. The DSTATCOM helps to improve the power factor and eliminate the Total Harmonics Distortion (THD) drawn from a Non-Liner Diode Rectifier Load (NLDRL).

Bhim Singh, Kamal AlHaddad&Ambrish Chandra, presents a comprehensive review of active filter (AF) configurations, control strategies ,selection of components, other related economic and technical considerations, and their selection for specific applications. It is aimed at providing a broad perspective on the status of A F technology to researchers and application engineers dealing with power quality issues. A list of more than 200 research publications on the subject is also appended for a quick reference.

B. P. McGrath and D. G. Holmes, presents the design, development and performance of a hybrid cascaded multilevel inverter. The advantage of the proposed topology is that the modulation, control and protection requirements of each bridge are modular and it requires only a single dc source in each phase leg. A two-level H-bridge inverter using variable frequency inverted sine wave carrier modulation technique has been studied for total harmonic distortion (THD) and switching losses for fuel cell applications. A detailed study of the technique was carried out through MATLAB/SIMULINK for switching losses and THD. The results were verified experimentally. It was noticed that the proposed modulation strategy results in lower switching losses for a chosen THD as compared to the conventional strategies.

III. D-STATCOM

STATCOMs are employed at distribution and transmission levels – though for different purposes. When a STATCOM is employed at the distribution level or at the load end for power factor improvement and voltage regulation alone it is called DSTATCOM. When it is used to do harmonic filtering in addition or exclusively it is called Active Power Filter. In the transmission system STATCOMs handle only fundamental reactive power and provide voltage support to buses. In addition STATCOMs in transmission system are also used to modulate bus voltages during transient and dynamic disturbances in order to improve transient stability margins and to damp dynamic oscillations.

In a synchronous link where two a.c sources of same frequency are connected together by means of a link inductor, active power flows from the leading bus to the lagging one and reactive power flows from the source with higher voltage magnitude to the one with lower voltage magnitude. The active power flow is almost entirely decided by the lead angle whereas the reactive flow is almost entirely decided by the difference in voltage magnitudes provided the inductor is loss free ,the lead angle is small (less than 15 degrees) and the voltage magnitude difference is small(less than 0.1 p.u) . The situation changes slightly if the link contains resistance. If two sources V1 with a phase angle of μ and V2 with a phase angle of 0 are connected together by means of an inductive link of impedance (R+jX) ohms and if the active power flowing into the source V2 is constrained to be zero (because this represents the STATCOM situation) the power delivered by the source V1 (which will not be zero and it will be equal to the power absorbed by the resistance in the link) and the reactive power delivered to the link by the source V2 will be given by the following relations (after a little algebra along with the assumptions that μ is small and R << X).

Active Power Delivered by V1

$$P = (V1^2/R)\,\mu^2 \text{ Watts} \qquad (1)$$

Reactive Power Delivered by V2 is

$$Q = (V1V2/R)\,\mu \text{ VArs} \qquad (2)$$

where the powers are for a phase and voltages have phase values. These relations can be used upto about 20 degrees for μ .Active Power drawn from the source V1 is independent of sign of phase angle (only V1 can supply losses in R because of the zero active power constraint at V2) whereas the reactive power delivered by V2 is directly proportional to the phase angle. In the STATCOM context, the source V1 is the power system voltage at the bus where the STATCOM is connected, V2 is the a.c voltage generated by the Inverter in the STATCOM, R is the total loss resistance in the link comprising the winding losses in the link inductor, interface magnetic and the inverter switches and snubbers etc. The Phase Angle of V1 w.r.t V2 is

μ = (R/X) (V2-V1)/V1................. (3)

This shows that the relative phase angle is linearly related to the voltage magnitude difference (for small differences) and hence the reactive power delivered by V2 is proportional to the voltage magnitude difference. Thus Q is proportional to μ or equivalently to (V2-V1). Both points of view will be useful later to understand the two different ways in which STATCOM can be controlled. In the STATCOM, the required a.c voltage source V2 is generated by inverting the D.C. voltage, which is assumed available across the capacitor in the D.C. side. But if the active power which goes into the inverter from the mains is kept zero, the initially charged capacitor will soon discharge down to zero due to active power losses in the Inverter which the D.C. side will have to supply. The D.C. side voltage will remain constant (or at least controlled) if the power drawn from mains is just enough to supply all the losses which take place everywhere due to the flow of demanded reactive current. The following relation may be derived for the D.C. side ca voltage under this condition. The D.C. side voltage is

Vd = (V1/k)(1-(X/R) μ) volts.............(4)

where V1 is the rms phase voltage of a.cmains, k is a constant, which also absorbs the modulation index of PWM process in the inverter. Keep the D.C. side voltage constant by controlling the value of μ .And control the reactive power from the inverter by directly changing (V2-V1) by controlling the modulation depth (i.e. the multiplication factor that comes between the D.C. voltage and the amplitude of a.c output in the Inverter).It should be obvious from the equations 1 to 4 that this strategy will result in an interacting control system. Fig.1 shows the Dc voltage.

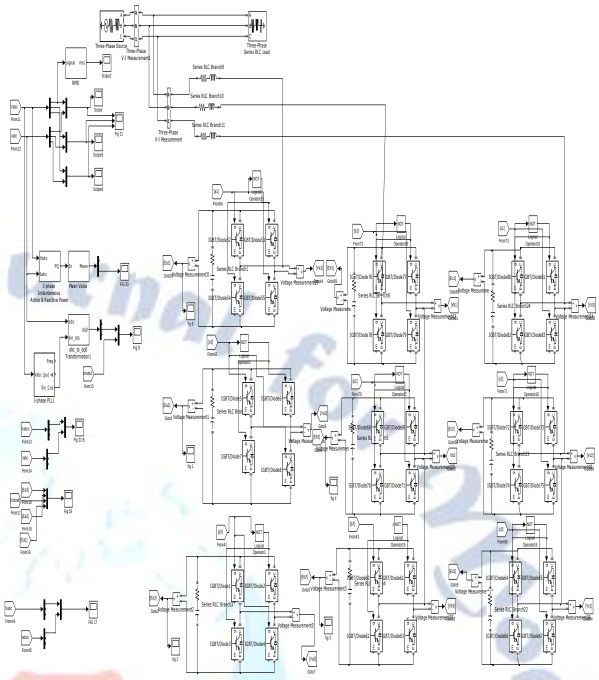

Fig1.Simulation Circuit

IV. SIMULATION RESULTS

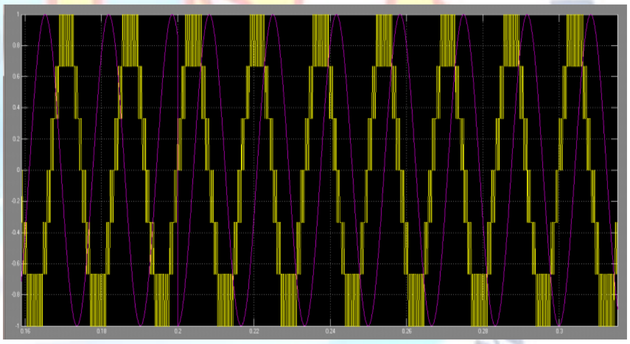

Fig.2 Seven level Voltage Waveform

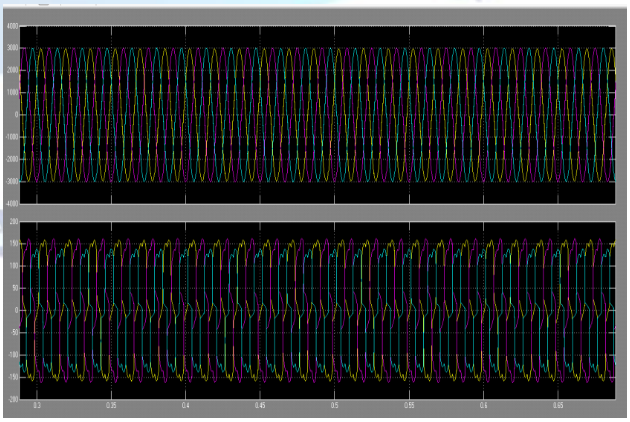

Fig.3 Three Phase Load Voltage and Load Current

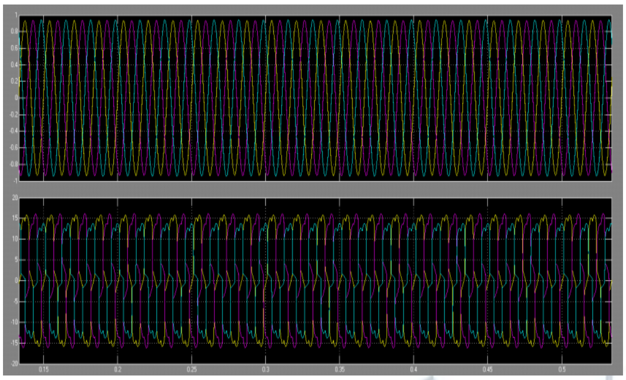

Fig.4 Source Voltage and Current

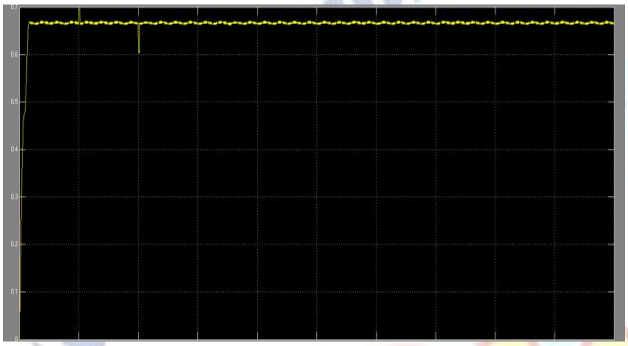

Fig.5 RMS Voltage.

V. Conclusion and Future Scope

A DSTATCOM with five level CHB inverter is investigated. Mathematical model for single H-Bridge inverter is developed which can be extended to multi H-Bridge. The source voltage , load voltage , source current, load current, power factor simulation results under nonlinear loads are presented. Finally Matlab/Simulink based model is developed and simulation results are presented.

A new control strategy is proposed in this thesis with focus on DC voltage regulation. This Research shows that the hybrid multilevel D-STATCOM performs satisfactory not only improving efficiency and waveform quality , but also compensating reactive power and negative-sequence current while maintaining DC voltage at the given value. The important advantages of this research based on hybrid multilevel converters using renewable source of energy are used for increasing voltage levels of output waveform, improving AC current quality, reducing switching frequency that results in low switching loss, as well as enhancing converter efficiency.

References

[1] K.A Corzine. and Y.L Familiant, "A New Cascaded Multi-level HBridge Drive:' IEEE Trans. Power. Electron, vol. I 7.no. I. pp. I 25-I 3 I, Jan 2002.

[2] J.S.Lai. andF.Z.Peng "Multilevel converters - A new bread of converters, "IEEE Trans. Ind.Appli .vo1.32. no.3. pp.S09-S17. May/ Jun. 1996.

[3] T.A.Maynard. M.Fadel and N.Aouda. "Modelling of multilevel converter:' IEEE Trans. Ind.Electron .vo1.44. pp.356-364. Jun. 1997.

[4] P.Bhagwat. andV.R.Stefanovic "Generalized structure of a multilevel PWM Inverter:' IEEE Trans. Ind. Appln, voI.IA-19.no.6, pp. I OS7-1069, Nov, Dec 1983.

[5] J.Rodriguez. Jih-sheng Lai, and F Zhengpeng, "Multilevel Inverters; A Survey of Topologies, Controls, and Applications," IEEE Trans. Ind. Electron., vol 49, n04., pp.724-738. Aug 2002.

[6] RoozbehNaderi, and Abdolrezarahmati, "Phase-shifted carrier PWM technique for general cascaded inverters," IEEE Trans. Power.Electron., vo1.23, no.3, pp.I 257-I 269.May.2008.

[7] Bhim Singh, Kamal AlHaddad and Ambrish Chandra, "A Review of Active Filter for Power Quality Improvements", IEEE Trans on Industrial Electronics, 46(S), pp.960970,1999

[8] Mauricio Angulo, Pablo Lezana, Samir Kouro, Jos'eRodr'lguez and Bin Wu, "Level-shifted PWM for Cascaded Multilevel Inverters with Even Power Distribution" IEEE Power Electronics specialist conference, 17-21 june 2007, pp.2373-2378, June 2007.

[9] B. P. McGrath and D. G. Holmes, "Multicarrier PWM strategies for multilevel inverters," IEEE Trans. Ind. Electron., vol. 49, no. 4, pp. 858-867, August 2002.