iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** IV **Month of publication:** April 2015

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

DC-DC Converter Based SHE-PWM Technique Multilevel Inverter

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Abstract— This paper presents a Selective Harmonic Elimination-PWM technology (SHE-PWM) employing H-Bridge multilevel inverter configuration. In this method variable DC voltage is used and the lower order harmonics are eliminated, without affecting the structure of the inverter. This method gives constant switching angle, so it reduces the number of steps required for offline calculation. The proposed method optimizes the DC-DC converter topology for high efficiency with high voltage capacity. In this paper a Buck-Boost converter is used. Current and voltage closed loop controllers are used to meet reactive power demand under varying load condition. The matlab simulink shows the output result.
Keywords- SHE-PWM, H-Bridge Inverter, reactive power compensation

I. INTRODUCTION

The reactive power compensation is a important factor in power network. The large penetration of renewable sources, which are intrinsically uncertain and highly variable by nature as an effective means of power generation has arisen new challenges to power networks. Nonlinear loads such as single phase ac tractions systems make the network to operate under undesired conditions [i.e., distorted, uncontrolled reactive power (VAR)], restricting the maximum active power transfer and significant unbalance enforcement. During this conditions the compensation is needed. Due to the advancement in FACTS devices the compensation is made simple. There are many devices are available to compensate the reactive power .In all among FACTS controllers the STATCOM system has better compensating capability than other controllers. It is a shunt compensation device. STATCOM can absorb or release reactive power instantaneously by adjusting the amplitude and phase of voltage/current on the AC side, Compared to Static Var Compensator (SVC), STATCOM can compensate harmonics and reduce the size of inductor and capacitor with fast dynamic response and wide operation range. In this work the STATCOM system is considered. In this project a STATCOM system is used along with the multilevel inverter. This increases the efficiency of compensation. It can provide reactive power compensation without the dependence on the ac system voltage. By controlling the reactive power, a STATCOM can stabilize the power system, increase the maximum active power flow and regulate the line voltages. Faster response makes STATCOM suitable for continuous power flow control and power system stability improvement. The interaction between the AC system voltage and the inverter-composed voltage provides the control of the STATCOM var output. A H-Bridge inverter is used in this proposed scheme. The multilevel inverter fed STATCOM system gives modularity, extensibility and control simplicity.

A Selective Harmonic Elimination method is used in this paper. CB-PWM is by far the simplest technique to generate the required multilevel pulses through the intersection of a fundamental reference waveform with the dedicated disposition carrier. Although it is used in earlier systems, it has the following disadvantages:

It requires high switching frequency.
It offers high switching losses.
It does not offer any direct manipulation to the harmonic content.
It cannot be used in over modulation regions.
Presence of Lower order harmonics

SHE-PWM method gives the tight control of harmonics compared with the carrier based-PWM. Therefore, it is considered as competitive solution for medium- and high-power conversion systems such as STATCOM and other utility based inverters.

II.SHE-PWM METHOD

There are many popular methods are used to reduce the harmonics in order to get an effective results. The popular methods for high switching frequency are Sinusoidal PWM and Space Vector PWM. For low switching frequency methods are space vector modulation and selective harmonic elimination. The SPWM technique has disadvantage that it cannot completely eliminate the low order harmonics. Due to this it cause loss and high filter requirement is needed. In Space Vector Modulation technique cannot be applied for unbalanced DC voltages. SHE PWM technique uses many mathematical methods to eliminate specific harmonics such as 5th, 7th, 11th, and 13th harmonics. The popular Selective Harmonic Elimination method is also called fundamental switching frequency based on harmonic elimination Theory.

III. HARMONIC ELIMINATION THEORY

By applying Fourier series analysis, the output voltage can be obtained. Fourier Series is an infinite sum of trigonometric functions that are economically related as,

F(t) $- ao + \sum_{n=1}^{\infty} c(n) \cos(2\pi n fo + \phi(n))$.

n= integer multiple,

ϕ(n)=initial phase for nth harmonic

ao,c(n)=fourier co-efficients

The output voltage equation derived for different voltage sources is given below,

$$\boldsymbol{v(t)} = \sum_{n=1,3,5}^{\infty} \frac{4V_{dc}}{n\pi}((v_1 \cos(n\varphi_1) + v_2 \cos(n\varphi_1) \ldots v_s \cos(n\varphi_2))\sin(n\omega t)$$

For a balanced three phase system, triplen harmonics are eliminated automatically by using line-line voltages so only non-triplen odd harmonics are present. To minimize harmonic distortion and to achieve adjustable amplitude of the fundamental component, up to (s-1) harmonic contents can be removed from the voltage waveform.

In order to achieve a wide range of modulation indexes with minimized THD for the synthesized waveforms, a generalized selective harmonic modulation method is proposed, which is called virtual stage PWM.

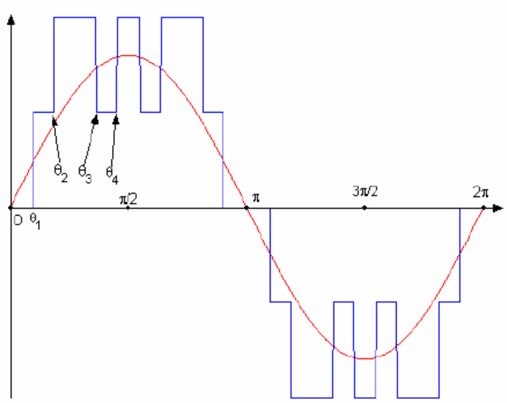

Fig.1.Output waveform of virtual phase PWM control

IV. CASCADED MULTILEVEL INVERTER

Cascade Multilevel Inverter (CMLI) is one of the most important topology in the family of multilevel and multi pulse inverters .It requires least number of components with compare to diode-clamped and flying capacitors type multilevel inverters and no specially designed transformer is needed as compared to multi pulse inverter. It has modular structure with simple switching strategy and occupies less space. The CMLI consists of a number of H-bridge inverter units with separate dc source for each unit and is connected in cascade or series as shown in Fig. 1. Each H-bridge can produce three different voltage levels: $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to ac output side by different combinations of the four switches *S1*, *S*2, *S3*, and *S4*. The ac output of each H-bridge is connected in series such that the synthesized output voltage waveform is the sum of all of the individual H-bridge outputs.

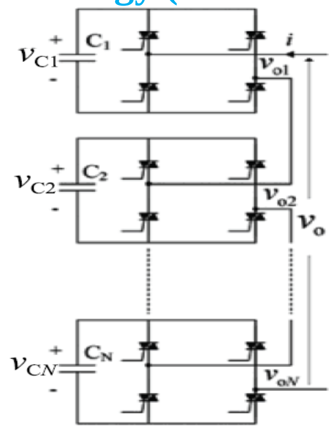

Fig.2. Circuit diagram of Cascaded H-Bridge Inverter

The most attractive features of multilevel inverters are as follows.
They can generate output voltages with extremely low distortion and lower dv\dt.
They draw input current with very low distortion.
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.
They can operate with a lower switching frequency.

V. BUCK-BOOST CONVERTER

The buck–boost converter is a type of DC-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer.

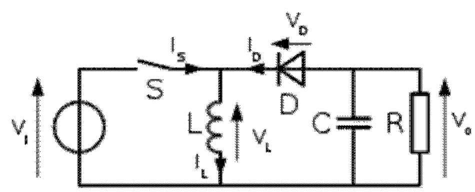

Fig.3.Circuit diagram of buck-boost converter

The basic principle of the buck–boost converter is:
while in the On-state, the input voltage source is directly connected to the inductor (L). This results in accumulating energy in L. In this stage, the capacitor supplies energy to the output load.
while in the Off-state, the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R
Compared to the buck and boost converters, the characteristics of the buck–boost converter are mainly:
polarity of the output voltage is opposite to that of the input
the output voltage can vary continuously from 0 to $-\infty$(for an ideal converter).

VI. PROPOSED STATCOM

The proposed method relies on the availability of the variable dc-voltage levels which can be easily obtained by advanced dc-dc converters. With the rapid growth in semiconductor devices industry and advanced materials such as nanocrystalline soft magnetic core that offers high saturation flux density (more than 1.2 T) and high relative permeability (over 10 000 at 100 kHz), leading to an extremely low core loss. The combination of the magnetic core with the latest trench-gate IGBTs and super-junction MOSFETs has made it possible to improve the system efficiency of the dc-dc converters up to 97% or higher. In the near future, the emergence of SiC switching devices and a new magnetic core material will allow the system efficiency to reach higher than 99%. This revolution leads to produce relatively medium- to high-voltage dc-dc converters with high-switching frequencies ranges from 5 kHz and as high as 50 kHz which proposed for different applications including grid-connected converters, PV integration with the grid, etc. The nonlinear, time invariant state space averaged equation which describes the lower frequency behaviour of the buck-boost converter based on two modes of operation (i.e., on and off) is given by

$$\frac{dX}{dt} = [A_1]\,X + [B_1 D]\,U$$

By taking Laplace transform, a linear dc-output voltage $v_{DC}(s)$ equation is,

$$v_{DC}(s) = \left(\frac{v_{SO} D_O(s)}{s^2 LC + s\frac{L}{R_B} + 1}\right) + \left(\frac{V_{SO} d(s)}{s^2 LC + s\frac{L}{R_B} + 1}\right)$$

where the first bracket defines the buck converter's input voltage deviation at the operating point and the second bracket defines the buck-boost converter's transfer function Gconv (s) for designing the voltage closed loop controller Gv (s).

VII. SIMULATION RESULTS

The implementation of the proposed line to- neutral MSHE–PWM voltage waveform produced by the STATCOM system can be observed that the intended low order non triplen harmonics (i.e., fifth, seventh, eleventh, thirteenth, seventeenth, ninteenth, twenty-third, twenty-fifth, and twenty-ninth) which were meant to be eliminated. The proposed MSHE–PWM switching method possesses eight switching angles per quarter cycle (i.e., 32 switching angles per one cycle) that make the effective switching frequency of the inverter equals to 1.6 kHz (i.e,. 32∗50 Hz). To further show the effectiveness of the proposed technique in producing a high-quality output voltage waveform, the same STATCOM system is operated and compared with the conventional POD CB-PWM with an equivalent switching frequency of 1.6 kHz. proposed MSHE–PWM with variable dc-voltage levels technique, reveals that the harmonics are tightly controlled even in the case when in the inverter operates in over modulation region.

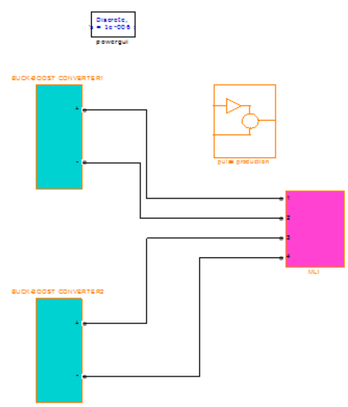

Fig.4.Matlab Simulation

The multi level inverter block contains 2 cascaded multilevel inverter bridges. Here the Buck-Boost Converter is used to give the input to the inverter blocks. The semiconductors are fed by a SHE-PWM pulses.

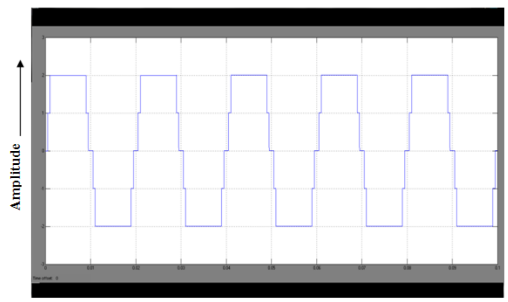

Fig.5.Output waveform of five level Multilevel inverter

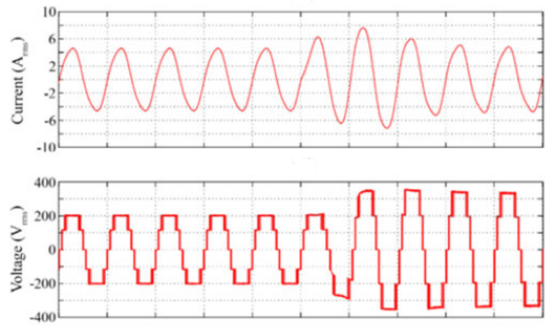

Fig.6.Simulation result of a grid current and STATCOM voltage

The simulation results shows the performance of SHE-PWM multilevel inverter fed STATCOM system.The variable DC voltage is given to the inverter via buck-boost dc-dc converter.

VIII. CONCLUSION

A Multilevel Selective Harmonic PWM Control method is presented in this paper. The performance of the control method is verified through MATLAB simulink .The lower order harmonics are eliminated in this control method.
Variable dc-voltage sources were obtained through a simple dc-dc converter, where the advancement and the rapid development in power semiconductors devices promised high efficiency dc–dc conversion systems. Although only buck-boost converter was considered in this paper. This also increases the system performance.

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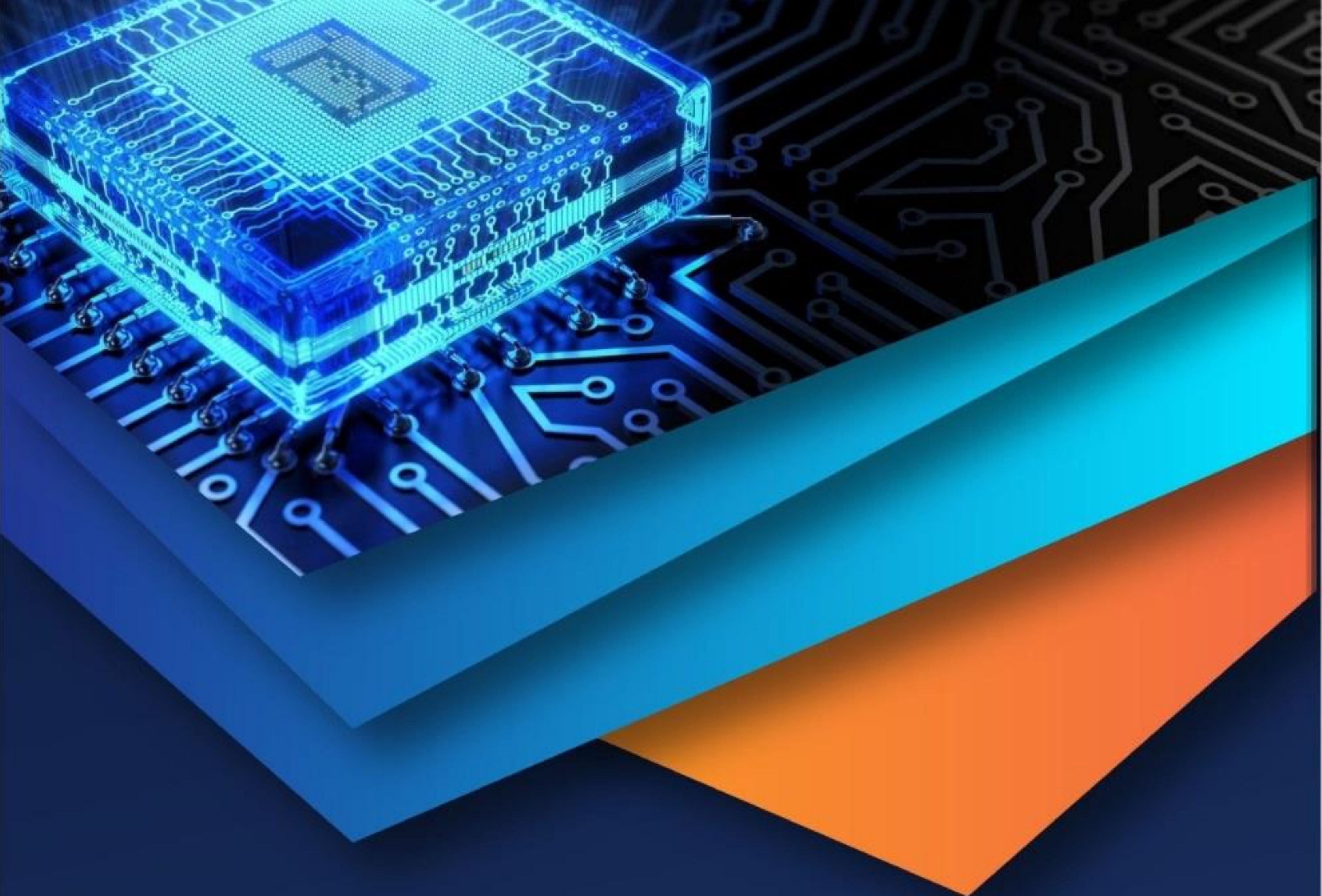

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