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Buck Converter Based She-PWM Technique Five Level Inverter Control for Statcom Applications

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Abstract – This paper presents a multilevel Selective Harmonic Elimination-PWM Technology(SHE-PWM) for STATCOM (Static Synchronous Compensator) system employing Five level H-bridge inverter configuration. In this method variable dc voltage is used and eliminate the lower order harmonics, with out affecting the structure of inverter circuit. By employing the multilevel selective harmonic elimination method, the constant switching angles are obtained and it reduces the number of steps for offline calculation. The proposed method optimizes the DC-DC converter topology for high efficiency with high voltage capacity. To explain the proposed method a dc-dc buck converter operating at only 2KHZ is used to provide the variable dc-voltage levels for each cell of the Five level H-bridge Inverter according to the modulation index m_i and also abc to dq transformation is used to compute the mathematical analysis easily. Current and voltage closed loop controllers are used to meet reactive power demand under varying load condition.

Index Terms – She-Pwm, Statcom, Buck converter, Cascaded H-bridge inverter.

1. INTRODUCTION

Power quality and efficiency issues occurs with unbalanced power flow becomes major problem in power systems which include low power factor, voltage collapse, unbalance, excessive harmonics, and oscillations. Low power factor system consists of linear and non-linear reactive loads which can draw more reactive power restricts the maximum active power transfer and causes losses to the power transmission and distribution systems. Voltage variations at line terminals such as voltage sags and voltage swells caused by the operation of equipment failure, sudden reduction in load on a circuit with a loose neutral connection. So,the reactive power compensation is an important factor in power network. Nonlinear loads such as single phase ac traction systems causes the system to operate under undesired conditions. During this conditions the reactive power compensation is essential or needed.

Due to the advancement in FACTS devices the reactive power compensation is simple. But there are so many devices to compensate the reactive power. Among all those FACTS controllers the STATCOM system has better compensating capability than other controllers. A static synchronous compensator (STATCOM) is also known as a static synchronous condenser (STATCOM) which is a regulating device used on alternating current electricity transmission networks. It is based on the power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power.

In this project a STATCOM system is used along with the five level 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 voltage. The STATCOM has so many advantages compared with the other FACTS controllers which can include fast and accurate dynamic response, small construction so that the construction cost is minimum, wide operating range, high efficiency, and high power decoupling capability. The interaction between the AC system voltage and inverter-composed voltage provides the control of the STATCOM var output.

A Five level H-bridge inverter is used in this proposed scheme because due to its modularity, extensibility and control simplicity. The choice of modulation technique plays an important role in a STATCOM control system. There are several PWM Techniques are available. Among all those selective harmonic elimination method is used in this paper. Carrier based PWM technique is used in earlier systems, but it has some disadvantages:

1) It requires high switching frequency.
2) It offers high switching losses.
3) It cannot be used in over modulation regions.

SHE-PWM method gives the tight control of harmonics when compared with the carrier based PWM. So, it is the best solution for medium and high power conversion systems such as STATCOM.

2. SHE-PWM METHOD

There are many popular methods are used to reduce the lower order harmonics such as Sinusoidal PWM, Space Vector PWM to get an effective results. But these are used for high switching frequency methods which causes high switching power losses. The SHE-PWM and space vector modulation are used for low frequency methods. This SHE-PWM technique uses many numerical techniques to eliminate the specific harmonics such as 5th, 7th, 11th harmonics.

By applying the fourier series analysis the output voltage can be obtained. The output voltage equation derived for different voltage sources is given below

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

This PWM Technique says that unwanted undesirable harmonics can be neglected (eliminated) and fundamental component can be controlled by creating notches at predetermined angles. If 'n' switchings /1/4 cycle 'n-1' harmonics can be eliminated and magnitude of fundamental can be controlled. Suppose four switchings are taken for quarter cycle (α_1, α_2, α_3, α_4), the condition is $\alpha_1 < \alpha_2 < \alpha_3 < \alpha_4 < \pi/2$

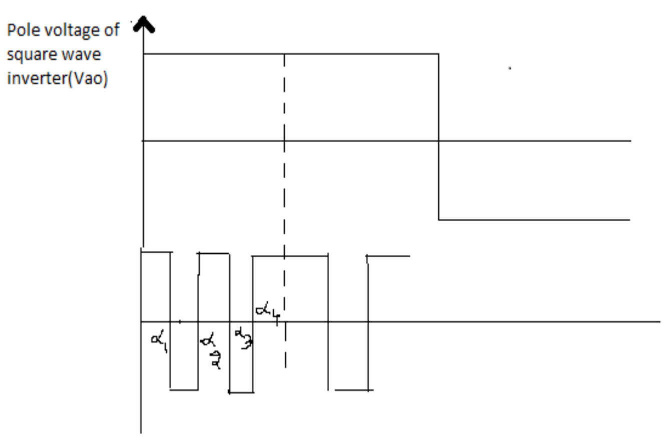

Fig: pole voltage of square wave Inverter

As the system is a three phase three wire system triplen harmonics can be eliminated no even harmonics present. To minimize harmonic distortion and to achieve the adjustable amplitude of the fundamental component up to (n-1) harmonic contents can be removed from the voltage waveform.

3. CASCADED MULTILEVEL INVERTER

CMLI is one of the most important topology in the family of multilevel inverters because it requires least number of components when compared with diode-clamped and flying capacitor type multilevel inverters and it occupies less space. This inverter uses several H-bridge inverters connected in series to provide a sinusoidal output voltage. Each cell contains one H-bridge and the output voltage generated by this multilevel inverter is actually the sum of all the voltages generated by each cell i.e. if there are m cells in a H-bridge multilevel inverter then number of output voltage levels will be 2m+1.

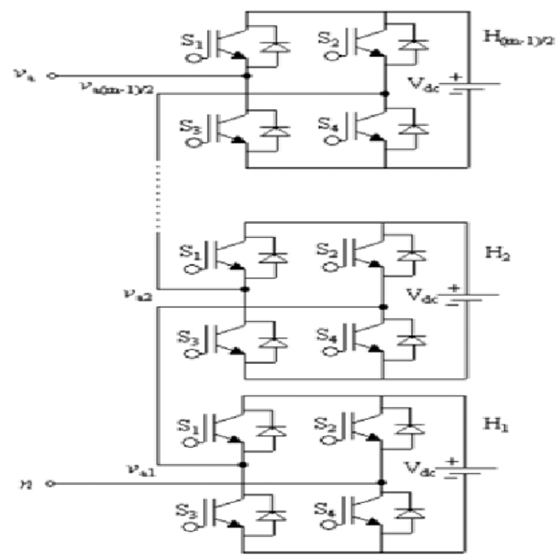

Fig:2 Circuit diagram of Cascaded H-bridge Inverter

The applications of cascaded multilevel inverters are:

1) Motor drives
2) Active filters
3) Electric vehicle drives.
4) Power factor compensators.
5) Back to back frequency link systems.

4. BUCK CONVERTER

The buck converter is a type of DC-DC converter that has an output voltage magnitude less than the input voltage magnitude. It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor) although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter).

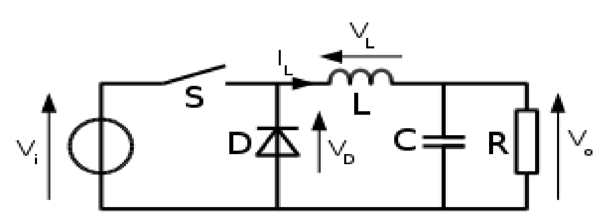

Fig:3 Circuit diagram of buck converter

The basic principle of the buck converter is

1. When the switch 'S' is closed the input voltage source is directly connected to the inductor(L) and the voltage across the inductor is V_l . The current through the inductor rises linearly. As the diode is reverse-biased by the voltage source V, no current flows through it.

2. When the switch 'S' is opened the inductor is connected to the output load and capacitor, so energy is transferred from L to C and R. As the diode is forward biased, the voltage across the inductor is small that is negligible so that Current decreases.

5. PROPOSED STATCOM

The proposed method relies on the availability of variable dc-voltage levels which can easily obtained by advanced dc-dc converters. Due to the rapid growth in semiconductor devices and materials, a soft magnetic core which has extremely low core loss is used. The combination of this magnetic core with the latest super junction MOSFETs have made it possible to improve the system efficiency of the dc-dc converters up to 97% or higher.

The non-linear, time invariant state space averaged equation which describes the lower frequency behaviour of the buck converter based on two modes of operation (i.e. on and off) is given by:

$$\frac{dX}{dt} = [A_1]X + [B_1D]U$$

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

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

Where the first bracket defines the buck converter's input voltage deviation at the operating point and the second bracket defines the buck converter's transfer function $G_{conv(s)}$ for designing the voltage closed loop controller $G_v(s)$

6. SIMULATION RESULTS AND DISCUSSIONS

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 1.6KHZ (i.e.,32*50 HZ). To further show the quality 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 1.6KHZ.

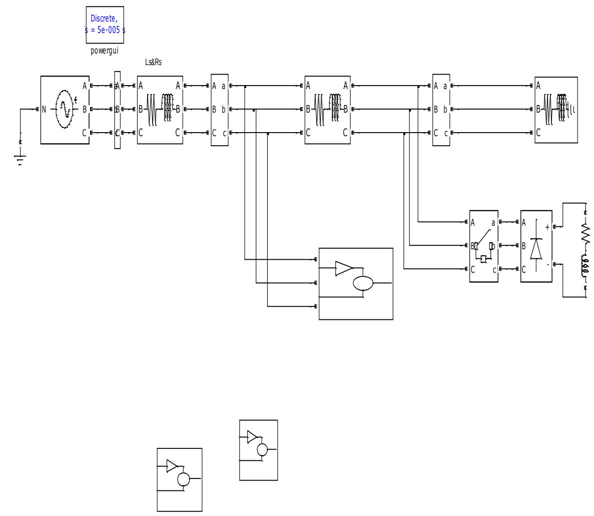

Fig:4 Matlab Simulation

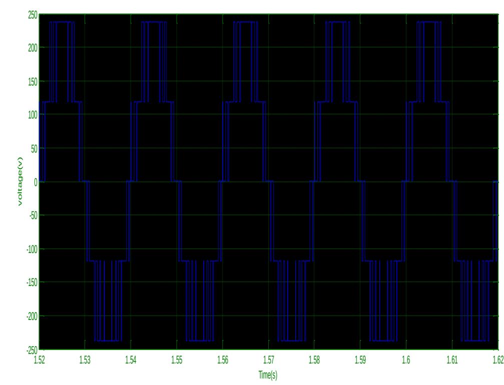

Fig:5 output waveform of five level Inverter

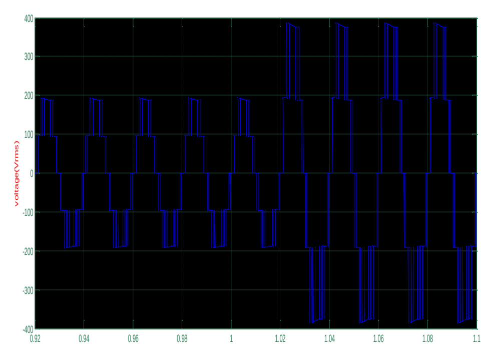

Fig:6 Simulation result of STATCOM voltage

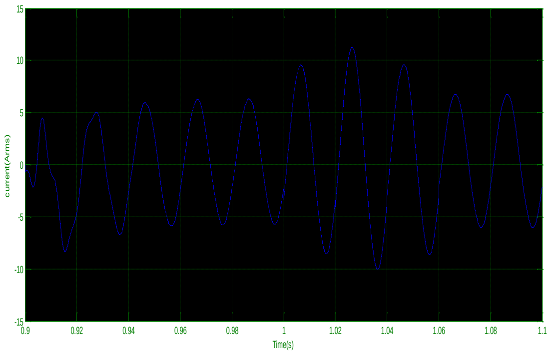

Fig:7 Simulation result of Grid current

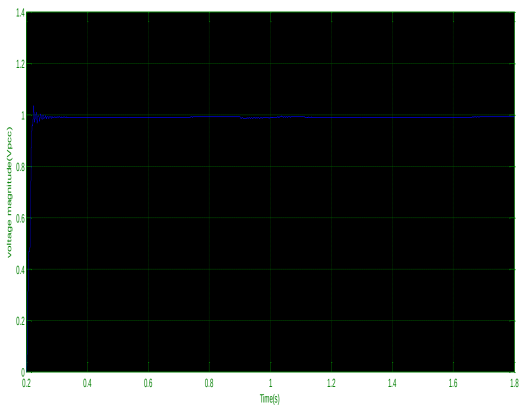

Fig:8 Simulation result of grid voltage magnitude(Vpcc)

The above figure illustrates the grid voltage sag which is caused by the voltage drop across the source impedance Zs when the load is changed from R-load to RL-load at a time of 1s. This voltage sag is then restored back to a unity by the proposed STATCOM system via reactive current compensation.

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 converter.

7. CONCLUSION

A New multilevel selective harmonic PWM control method for STATCOM is presented in this paper. The performance of the control method is verified using MATLAB simulink. The lower order harmonics are eliminated and the statcom voltage can be controlled in this control method.

Variable dc-voltage sources were obtained through a simple buck converter, where the advancement and the rapid development in power semiconductor devices with high efficiency dc-dc conversion systems.

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