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RESEARCH ARTICLE

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GRID CONNECTED THREE PHASE CASCADED H-BRIDGE MULTILEVEL BOOST INVERTER WITH NO INDUCTORS

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ABSTRACT

Renewable energy systems are getting to a greater extent and more far-flung with the increase in the electrical energy demand and the concern for the environmental pollution close to the world. Multilevel inverters (MLI) have gained much attention in the area of electrical energy system and control due to its vantages in high power applications with low harmonic. Out of different structures of MLIs, Cascaded H-Bridge (CHB) MLI is more suitable converter for renewable energy applications. This paper presents a DC- AC three phase cascaded H-bridge multilevel boost inverter with grid connected. The proposed design 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. A fundamental switching scheme is used to do modulation control and to produce a five-level phase voltage. MATLAB/SIMULINK simulation show that the proposed dc–ac three phase cascaded H-bridge multilevel boost inverter can output a boosted ac voltage without the use of inductors.

Key Words: DC-AC, Multilevel inverter (MLI) renewable energy system, IGBT/Diode’s.

INTRODUCTION

Energy and environment problem has received great attention all around the world. As a result, renewable energy is generally welcomed by the public for the characteristics of pollution-free and reserve-abundant [1-3]. To meet the self requirement of high efficiency and high reliability for the renewable energy source, the performance of the power electronics interface should be improved [3, 4]. Suitable topology and control method are needed to reach the high-level operation. The research work in the paper is focused on the DC-AC part in the renewable energy system.

A cascaded H-bridge multilevel boost inverter shown in Fig. 1 for renewable energy applications connected to grid is described in this paper. Traditionally, each H-bridge of a cascaded multilevel inverter needs a dc power supply [4]–[6]. The proposed cascaded H-bridge multilevel boost inverter 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 [11]–[14]. In this topology, the need for large inductors is eliminated. A fundamental switching scheme is used to do modulation control and to output five-level phase voltages. Simulation show that the proposed dc–ac cascaded H-bridge multilevel boost inverter without inductors can output a boosted ac voltage.

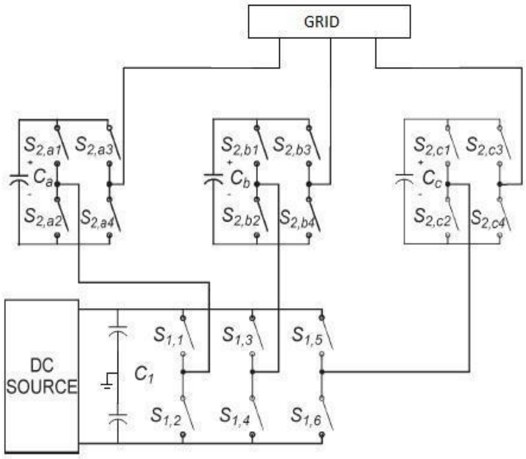

Figure 1: Topology of the proposed dc–ac cascaded H-bridge multilevel boost inverter.

Proposed Concept

The topology of the proposed dc–ac cascaded H-bridge multilevel boost inverter is shown in Fig. 1. The inverter uses a standard three-leg inverter (one leg for each phase) and an H-bridge with a capacitor as its dc source in series with each phase leg.

To see how the system works, a simplified single phase topology is shown in Fig. 2. The output voltage $v1$ of this leg of the bottom inverter (with respect to the ground) is either $+Vdc/2$ ($S5$ closed) or $-Vdc/2$ ($S6$ closed). This leg is connected in series with a full H-bridge, which, in turn, is supplied by a capacitor voltage. If the capacitor is kept charged to $Vdc/2$, then the output voltage of the H-bridge can take on the values $+Vdc/2$ ($S1$ and $S4$ closed), 0 ($S1$ and $S2$ closed or $S3$ and $S4$ closed), or $-Vdc/2$ ($S2$ and $S3$ closed). An example output waveform from this topology in figure.3. When the output voltage $v = v1 + v2$ is required to be zero, one can either set $v1 = +Vdc/2$ and $v2 = -Vdc/2$ or $v1 = -Vdc/2$ and $v2 = +Vdc/2$.

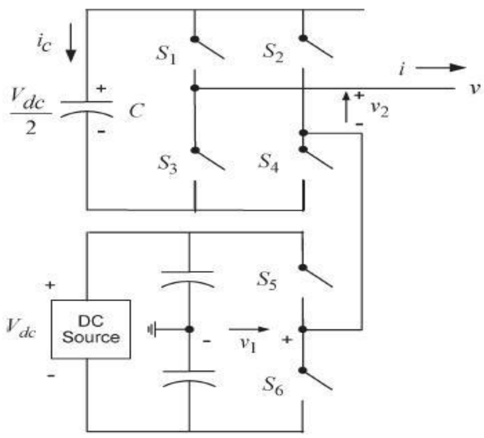

Figure 2: Single phase of the proposed dc–ac cascaded H-bridge multilevel boost inverter.

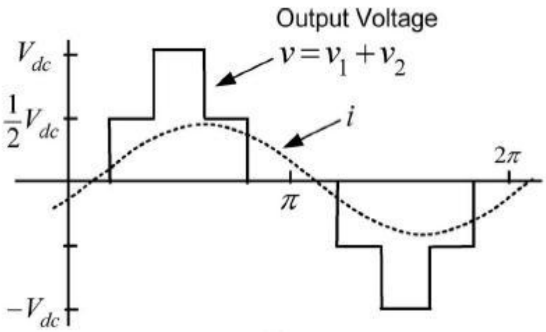

Figure 3: Output Voltage and Current Waveform.

The capacitor is kept charged, consider the interval $\vartheta 1 \leq \vartheta \leq \pi$, the output voltage in Fig. 3 is zero, and the current $i > 0$. If $S1$ and $S4$ are closed (so that $v2 = +Vdc/2$) and $S6$ is closed (so that $v1 = -Vdc/2$), then the capacitor is discharging $ic = -i < 0$; and $v = v1 + v2 = 0$. On the other hand, if $S2$ and $S3$ are closed (so that $v2 = -Vdc/2$) and $S5$ is also closed (so that $v1 = +Vdc/2$), then the capacitor is charging $ic = i > 0$; and $v = v1 + v2 = 0$. The case $i < 0$ is accomplished by simply reversing the switch positions of $i > 0$ case for charging and discharging of the capacitor. Consequently, the method consists of monitoring the output current and the capacitor voltage, so that during periods of zero voltage output, either the switches $S1$, $S4$, and $S6$ are closed or the switches $S2$, $S3$, and $S5$ are closed, depending on whether it is necessary to charge or discharge the capacitor. It is this flexibility in choosing how to make that output voltage zero that is exploited to regulate the capacitor voltage.

The goal of using fundamental frequency switching modulation control is to output a five-level voltage waveform, with a sinusoidal load current waveform. If the capacitor's voltage is higher than $Vdc/2$, switches $S5$ and $S6$ are controlled to output voltage waveform $v1$, and the switches $S1$, $S2$, $S3$, and $S4$ are controlled to output voltage waveform $v2$.

If the capacitor's voltage is lower than $Vdc/2$, the switches $S5$ and $S6$ are controlled to output voltage waveform $v1$, and switches $S1$, $S2$, $S3$, and $S4$ are controlled to output voltage waveform $v2$. Therefore, the capacitors' voltage can be regulated by alternating the capacitor's charging and discharging control, when the inverter output is 0 V. This method of regulating the capacitor voltage depends on the voltage and current not being in phase. That is, one needs positive (or negative) current when the voltage is passing through zero in order to charge or discharge the capacitor. Consequently, the amount of capacitor voltage the scheme can regulate depends on the phase angle difference of output voltage and current. In other words, the highest output ac voltage of the inverter depends on the displacement power factor of the load.

Switching Control

There are several kinds of modulation control methods such as traditional sinusoidal pulse width modulation (SPWM), [5]–[9], space vector PWM [12], harmonic optimization or selective harmonic elimination [10]–[12], and active harmonic elimination [11], and they all can be used for inverter modulation control. For the proposed dc–ac boost inverter control, a practical modulation control method is the fundamental frequency switching control for high output voltage and SPWM control for low output voltage, which only uses the bottom inverter. In this paper, the fundamental frequency switching control is used.

The Fourier series expansion of the fundamental frequency (staircase) output voltage waveform of the multilevel inverter, as shown in Fig. 3, is

$$V(\omega t)=\frac{4V_{dc}}{\pi\ 2}\times\sum_{n=1,3,5,\ldots}^{\infty}\frac{1}{n}(\cos(n\theta_1)+\cos(n\theta_2))\sin(n\omega t).$$

The key issue of fundamental frequency modulation control is choice of the two switching angles $\vartheta 1$ and $\vartheta 2$. In this paper, the goal is to output the desired fundamental frequency voltage and to eliminate the fifth harmonic. Mathematically, this can be formulated as the solution to the following:

$$\cos(\theta_1) + \cos(\theta_2) = m_a$$
$$\cos(5\theta_1) + \cos(5\theta_2) = 0.$$

This is a system of two transcendental equations with two unknowns' $\theta 1$ and $\vartheta 2$, and *ma* is the output voltage index. Traditionally, the modulation index is defined as

$$m = \frac{V_1}{V_{\rm dc}/2}.$$

Output Voltage Boost

As previously mentioned, the cascaded H-bridge multilevel inverter can output a boosted ac voltage to increase the output power, and the output ac voltage depends on the displacement power factor of the load. Here, the relationship of the boosted ac voltage and the displacement power factor is discussed. It is assumed that the load current displacement angle is ϕ, as shown in Fig. 3. To balance the capacitor voltage, the net capacitor charging amount needs to be greater than the pure discharging amount. That is, to regulate the capacitor's voltage

Modeling & Simulation Results

Figure 4 show the modeling of Single phase cascaded H bridge multilevel boost inverter. Simulation in MATLAB/SIMULINK observed. In modeling the proposed topology inverter connected with R-Load (Resistance R=1kohm). This Proposed single phase inverter constructed one half bridge and one full bridge in cascaded connection. A 230V DC source applied to below Half bridge inverter and full bridge inverter connected in series with Capacitor (C=10000e-6), single phase load voltage waveform and current waveforms show in following results.

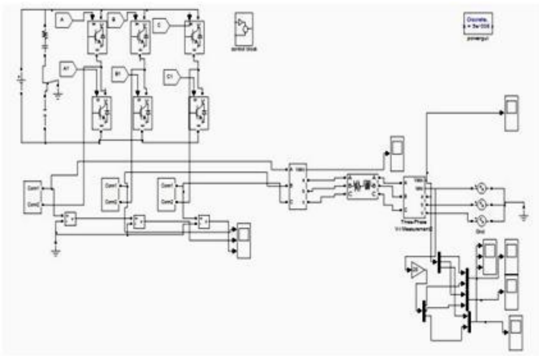

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Figure 4: Proposed single Phase Five level inverter with R-Load.

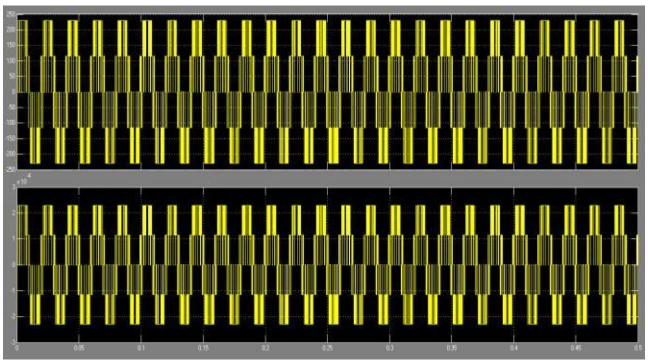

Figure 5: Proposed Single phase Five level inverter (a) Voltage, (b) current waveform.

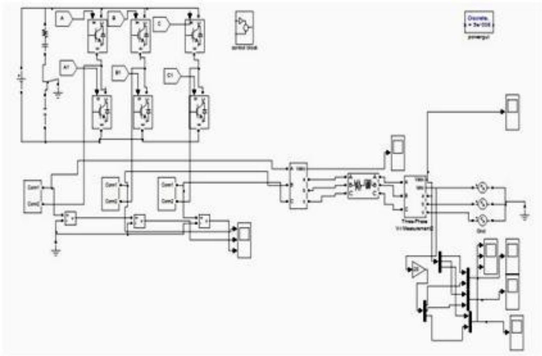

Figure 6: Modeling of Proposed H-bridge multilevel boost inverter with grid connection.

Figure 6 show the modeling of grid connected three phase cascaded H bridge multilevel boost inverter for renewable energy system. Simulation in MATLAB/SIMULINK observed. In modeling the proposed topology inverter connected to grid with grid impedance (Resistance R=500ohm & inductance L=10mH). A 230V DC source applied to below three leg inverter and the output given three phase AC 440V, 50Hz. Grid source Parameters are 440V, 50Hz, three phase voltage source show in following results.

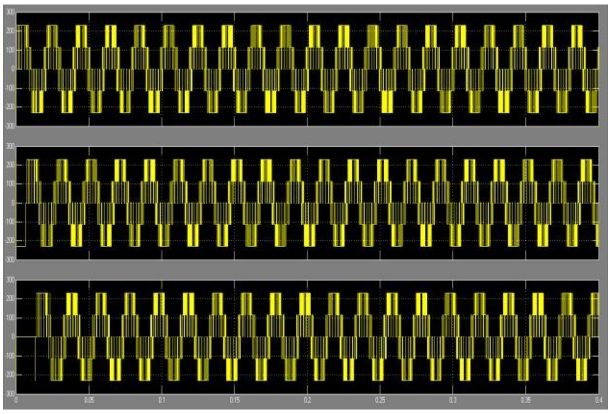

Figure 7: Each phase output voltage.

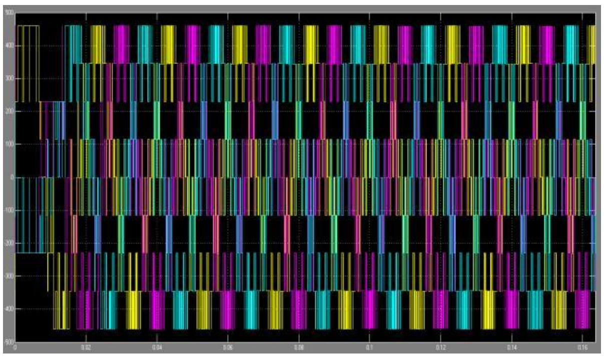

Figure 8: Three phase output voltage.

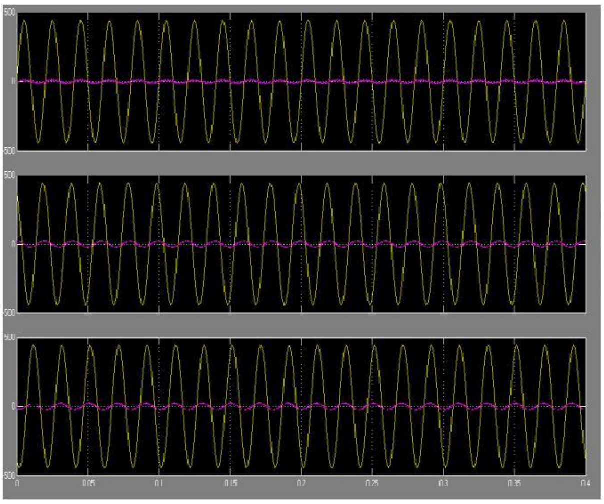

Figure 9: Each phase grid voltages and currents (Power factor unity).

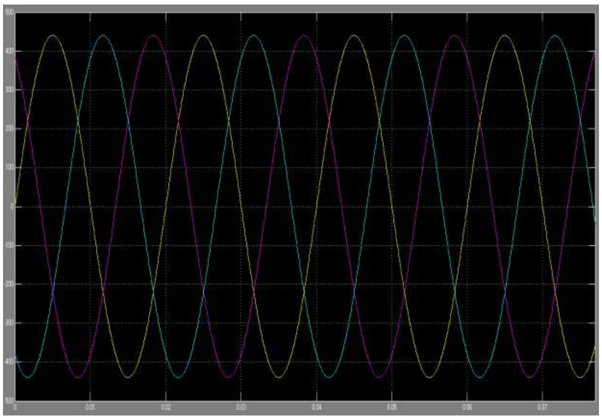

Figure 10: Three phase grid connected voltage.

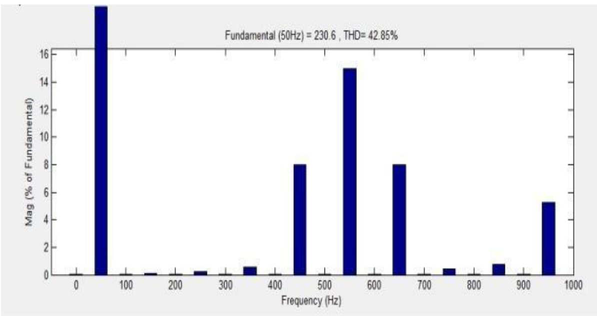

Figure 11: THD of output voltage.

The simulation results and their FFT analysis all verified the performance of the fundamental frequency switching control. In this experiment, to achieve the highest output voltages for the cascaded multilevel boost inverter without inductors and the traditional inverter, two steps were involved. First, the load was connected to the bottom traditional inverter to output its highest voltage; second, the load was connected to the cascaded H-bridge multilevel inverter with the same dc power supply voltage. In THD low order harmonics like 3^{rd} and 5^{th} are very low shown in figure 11.

CONCLUSION

The proposed cascaded H-bridge multilevel boost inverter without inductors uses a standard three-leg inverter (one leg for each phase) and an H-bridge in series with each inverter leg. A fundamental switching scheme is used for modulation control, to output five-level phase voltages. IGBT's are used in this circuit, Simulation results show that the proposed dc– three phase ac cascaded H-bridge multilevel boost inverter can output a boosted ac voltage with the same dc power supply, low switching losses and low harmonics. Grid connection point it is very suitable because of low harmonics, smooth waveforms and high efficiency.

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