저비용 단일전원 비대칭 Cascaded H-Bridge 멀티레벨 인버터

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Low Cost Single-Sourced Asymmetrical Cascaded H-Bridge Multilevel Inverter

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ABSTRACT

Recently, asymmetrical cascaded H-bridge multilevel inverter started to be highlighted as an alternative for the symmetrical cascaded H-bridge. The topology has a small number of part count compared to the symmetrical with higher number of levels. However, it has a drawback of the modulation index limitation which is relatively higher than its symmetrical counterpart, which causes a necessity of an extra voltage pre-regulator. In this paper, the single-sourced pre-regulator is unified with an inner single switch DC/DC converter isolated by coupled inductor. It leads to cost and size reduction. The proposed topology is verified using simulation results.

1. Introduction

Due to considerable increase in research activities in the field of renewable energy power conditioning systems (PCS), several multilevel inverter based systems have been proposed in recent years [1]. Using multilevel inverters provides inherent advantages like high power quality, low voltage stress, reduction in filter size and high efficiency. Among the several types of multilevel inverters, cascaded H-bridge (CHB) type of inverters have been preferred in photo-voltaic systems. CHB inverters provide simplified integration into PCS since it is essentially comprised of several H-bridge cells connected in series. CHB inverters are typically classified into two types: Symmetric and Asymmetric CHB inverters. H-bridge cells in symmetric CHB are modular in nature, hence providing ease of scalability in PCS. Though asymmetric CHB inverters are not modular in nature, they provide higher number of voltage levels in output compared symmetric CHB inverters with same number of H-bridge cells.

Asymmetric CHB inverters require isolated DC sources to their individual H-bridge cells. Since each H-bridge cell is not modular, the DC-link voltage required is varied for each cell. Apart from this, a minimum modulation index value is required to obtain optimum number of voltage levels in the output. This results in a major drawback for using asymmetric H-bridge inverters in photo-voltaic (PV) systems. Since the DC voltage produced by PV cells varies according to the atmospheric conditions, the optimum voltage levels are not obtained when the modulation index moves below a critical limit. In case of 7-level asymmetric CHB inverter this critical value of modulation index is 0.7. When the modulation index goes below this value, all the switches in the low voltage H-bridge are turned-OFF during the peak. Hence during this operation only 5-level output is available in the output and this deteriorates the THD of the output. Hence it becomes critical to prevent this scenario from happening in the PV systems. In this paper, a solution using a pre-stage DC-DC converter, with isolated charge pumped output, is used to obtain pre-regulation. A boost converter directly provides the DC-link voltage for the HV H-bridge cell and a coupled inductor charge pump with isolation is used to provide the DC-link voltage for the LV H-bridge. The charge pump output voltage is fixed by the transformer ratio to maintain voltage balance between the H-bridge cells. The operating principle of the proposed system is explained in the following section and the paper is concluded in the consecutive section.

2. Proposed System

The complete circuit diagram for the proposed Asymmetric CHB inverter with its pre-regulator is shown in figure 1. The proposed inverter contains two major sections.

2.1 Boost DC-DC converter with isolated charge pumped output

The step-up DC-DC converter with charge pumped output have been used in PV systems with Half-bridge inverter [2]. From figure 1 it can be seen that the pre-stage DC-DC regulator consists of a boost converter combined with the isolated charge pump output. The function of the boost converter is to regulate the DC-link voltage of the HV H-bridge at a preset fixed value. This prevents the modulation index from reaching the critical value. While the charge pump output provides the isolated DC-link voltage for the LV H-bridge. The voltage gain of the charge pump output depends on the transformer ratio as shown below

$$\frac{V_{dc/2}}{V_i} = \frac{1}{1-D}\frac{N_s}{N_p} \quad (1)$$

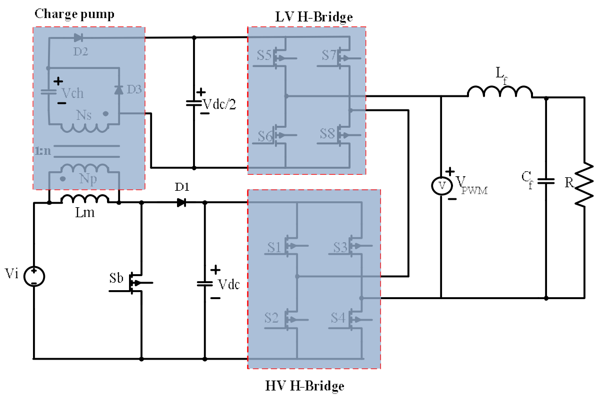

Fig 1. Circuit diagram of Asymmetric CHB inverter with isolated DC-DC pre regulation.

Also the CCM operation of the boost converter is ensured by choosing the value of the inductor Lm above the critical value. Figure 2 shows the current flow for the boost converter and charge pump circuit during ON/OFF conditions. It can be seen that the energy is stored in the boost inductor and the charge pump capacitor when switch (Sb) is turned ON. Similarly the stored energy is discharged when the switch is turned OFF.

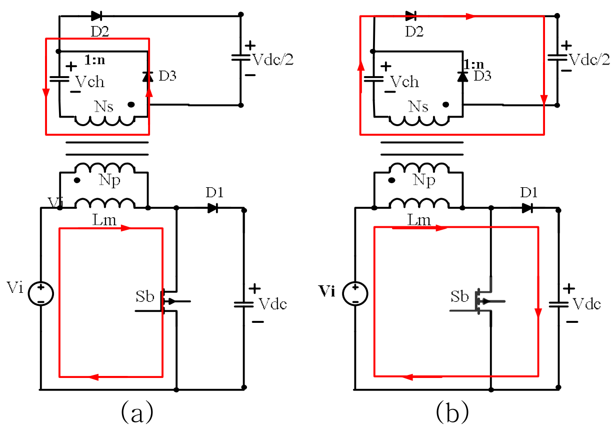

Fig 2. Current flow for the boost and charge pump circuit (a) Switch is ON (b) Switch is OFF.

2.2 Asymmetric CHB inverter

Asymmetric CHB inverter is chosen because it provides high number of voltage levels in the output compered to symmetric CHB inverter as shown below.

$$L=2N+1 \quad \text{(Symmetric)} \qquad (2)$$
$$L=2^{N+1}-1 \quad \text{(Asymmetric)} \qquad (3)$$

A continuous phase shifted modulation technique is used for the modulation of the inverter cells. A DC value of Vdc/2 is used as reference for the HV-H-bridge cell and the reference for the LV H-bridge cell is created by the subtracting the sinusoidal reference signal with the HV H-bridge output. This modulation provides 7-level output for the CHB cells. Table 1 shows the parameters used for the simulation file. Figure 3 shows the 7-level output of the asymmetric CHB inverter. It can be seen that the charge pump balances the DC-link voltage for the LV H-bridge cell at exactly half the Dc-link voltage of the HV H-bridge cell.

Parameters	Value
Input DC voltage (V_i)	120V
Magnetizing Inductance (L_m)	500 uH
Transformer ratio (n)	2:1
HV DC-Link voltage (V_{dc})	200V
Filter Inductance (L_f)	1.5mH
Filter Capacitance (C_f)	2uF
Load resistance (R)	50 ohm

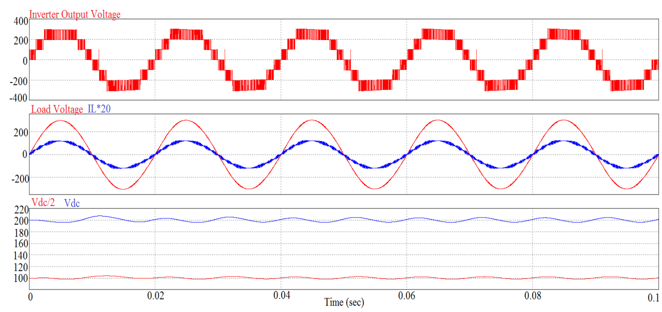

Fig 3. Simulation result for the proposed Asymmetric CHB with pre- regulation.

3. Conclusion

In this paper an Asymmetric CHB inverter with prest-age boost DC-DC converter for DC-link regulation is presented. This DC-link regulation is aimed to prevent critical modulation index limitation in single-sourced PV systems. A charge pump circuit is coupled with boost inductor in the circuit to provide isolated DC-link voltage for the LV H-bridge cell. The charge pump voltage output is determined by the transformer ratio hence providing regulated output. Due to the usage of reduced number of parts, the proposed system is cost effective and reliable. The proposed system is verified using simulation with 1kW output.

Reference

[1] K. Samir, M. Mariusz, K. Gopakumar, M. A. Perez, "Recent Advances and Industrial Applications of Multilevel Converters," IEEE. Trans. Industrial Electronics, vol. 57, no.8, August 2010.

[2] Woo-Young Choi and Jae-Yeon Choi "High-Efficiency Power Conditioning System for Grid-Connected Photovoltaic Modules", JOURNAL OF POWER ELECTRONICS, Vol. 11, No. 4, 561-567p, 2011.