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Implementation and Control of Hybrid Multilevel Converter with Floating Dc-Link for Current Waveform Improvement

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Abstract — *Multilevel converters offer advantages in terms of the output waveform quality due to the increased number of levels used in the output voltage modulation. This advantage is particularly true for cascaded H-bridge converters that can be built to produce a large number of levels thanks to their modular structure. Nevertheless, this advantage comes at the cost of multiple DC- links supplied by independent rectifiers through the use of a multi-output transformer for inverters. This frontend complicates the implementation of converters that have a high number of levels. An alternative method of using lower voltage cells with floating dc-links to compensate only for voltage distortion of an NPC converter is considered for active rectifier applications. The analogy between the floating H-bridges and series active filters is used to develop a strategy for harmonic compensation of the NPC output voltage and the control of the floating dc-link voltages. This simplifies the current control scheme and increases its bandwidth. Experimental results with a low power prototype that show the good performance of the proposed modulation technique and the resulting improvement in the output waveform are provided.*

INDEX TERMS-power electronics, current control, harmonic distortion

1.INTRODUCTION:

The smallest number of voltage levels for a multilevel inverter using cascaded inverter with SDCSs is three. To achieve a three-level waveform, a single full-bridge inverter is employed. Basically, a full-bridge inverter is known as an H-bridge cell, which is illustrated in Fig. 1.1. The inverter circuit consists of four main switches and four freewheeling diodes.

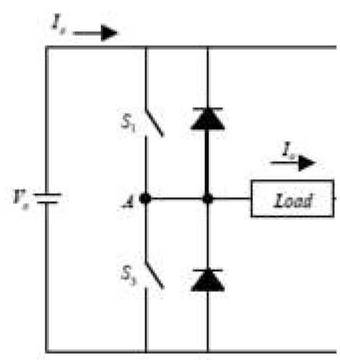

Figure 1 An H-bridge cell.

1.1 Gate Signal and Inverter Operation

According to four-switch combination, three output voltage levels, +V, -V, and 0,can be synthesized for the voltage across A and B. During inverter operation shown in Fig. 1.2, switch of S1 and S4 are closed at the same time to provide VAB a positive value and a current path for Io. Switch S2 and S4 are turned on to provide VAB a negative value with a path for Io. Depending on the load current angle, the current may flow through the main switch or the freewheeling diodes. When all switches are turned off, the current will flow through the freewheeling diodes.

2 CASCADE H-BRIDGE INVERTER

A single-phase structure of an m-level cascaded inverter is illustrated in Figure 31.1. Each separate dc source (SDCS) is connected to a single-phase full-bridge, or H-bridge, inverter. Each inverter level can generate three different voltage outputs, $+V_{dc}$, 0, and $-V_{dc}$ by connecting the dc source to the ac output by different combinations of the four switches, S_1, S_2, S_3, and S_4.

To obtain $+V_{dc}$, switches S_1 and S_4 are turned on, whereas $-V_{dc}$ can be obtained by turning on switches S_2 and S_3. By turning on S_1 and S_2 or S_3 and S_4, the output voltage is 0. The ac outputs of each of the different full-bridge inverter levels are connected in series such that the synthesized voltage waveform is the sum of the inverter outputs. The number of output phase voltage levels m in a cascade inverter is defined by m = 2s+1, where s is the number of separate dc

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sources. An example phase voltage waveform for an 11-level cascaded H-bridge inverter with 5 SDCSs and 5 full bridges is shown in Figure 2.1.2. The phase voltage

$$v_{an} = v_{a1} + v_{a2} + v_{a3} + v_{a4} + v_{a5}.$$

For a stepped waveform such as the one depicted in Figure 31.2 with s steps, the Fourier Transform for this waveform follows

$$V(\omega t) = \frac{4V_{dc}}{\pi}\sum_{n}\left[\cos(n\theta_1) + \cos(n\theta_2) + \ldots + \cos(n\theta_s)\right]\frac{\sin(n\omega t)}{n}, \quad \text{where } n = 1, 3, 5, 7, \ldots$$

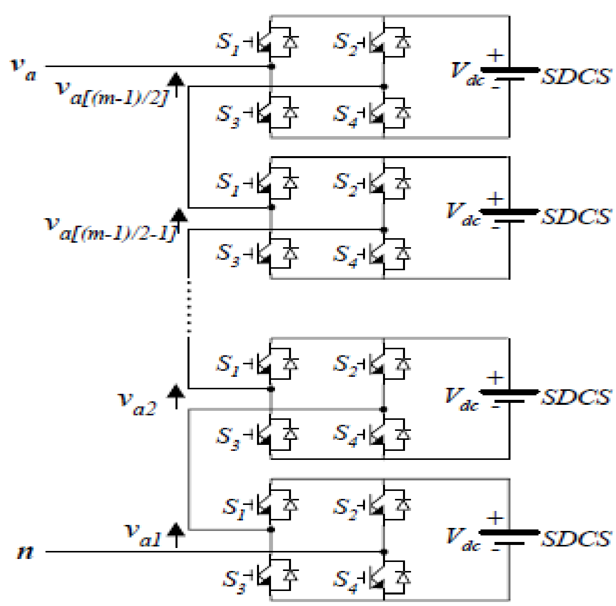

Fig 2. Single-phase structure of a multilevel cascaded H-bridges inverter

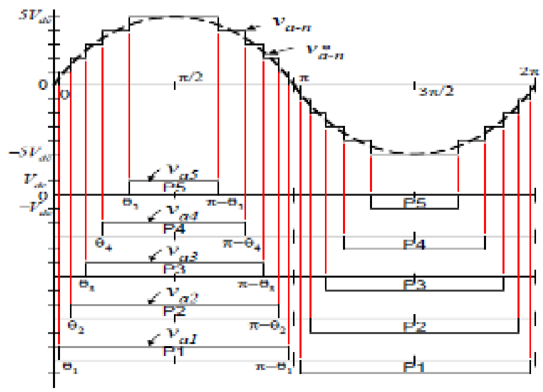

Fig 3. Output phase voltage waveform of an 11-level cascade inverter with 5 separate dc sources.

The magnitudes of the Fourier coefficients when normalized with respect to V_{dc} are as follows:

$$H(n) = \frac{4}{\pi n}\left[\cos(n\theta_1) + \cos(n\theta_2) + \ldots + \cos(n\theta_s)\right], \quad \text{where } n = 1, 3, 5, 7, \ldots$$

The conducting angles, θ_1, θ_2, ..., θ_s, can be chosen such that the voltage total harmonic distortion is a minimum. Generally, these angles are chosen so that predominant lower frequency harmonics, 5th, 7th, 11th, and 13th, harmonics are eliminated. More detail on harmonic elimination techniques will be presented in the next section.

Multilevel cascaded inverters have been proposed for such applications as static VAR generation, an interface with renewable energy sources, and for battery-based applications. Three-phase cascaded inverters can be connected in star, as shown in Figure 2.1.3, or in delta. Peng has demonstrated a prototype multilevel cascaded static VAR generator connected in parallel with the electrical system that could supply or draw reactive current from an electrical system. The inverter could be controlled to either regulate the power factor of the current drawn from the source or the bus voltage of the electrical system where the inverter was connected.

Cascaded inverters are ideal for connecting renewable energy sources with an ac grid, because of the need for separate dc sources, which is the case in applications such as photovoltaic's or fuel cells.

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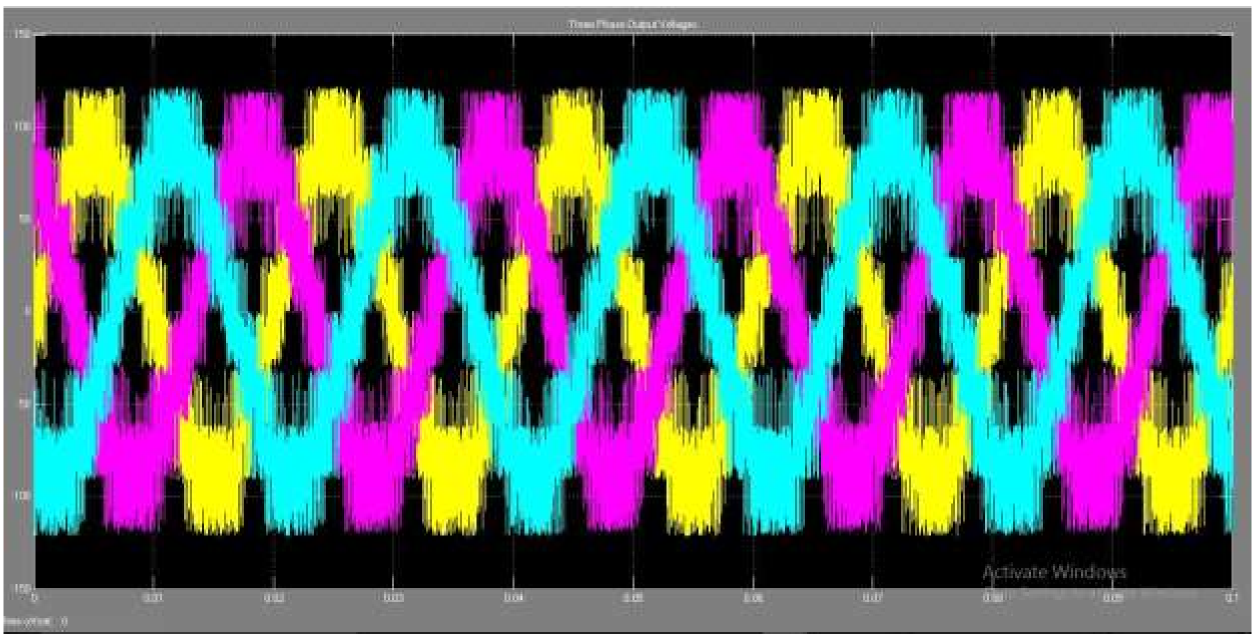
Cascaded inverters have also been proposed for use as the main traction drive in electric vehicles, where several batteries or ultra capacitors are well suited to serve as SDCSs. The cascaded inverter could also serve as a rectifier/charger for the batteries of an electric vehicle while the vehicle was connected to an ac supply as shown in Figure 2.3 Additionally, the cascade inverter can act as a rectifier in a vehicle that uses regenerative braking.

RESULTS



CONCLUSION

This paper has presented the series connection of a SHE modulated NPC and an HB multilevel inverter with a novel control scheme to control the floating voltage source of the HB stage. The addition of the HB series active filter or additional converter stage is not intended to increase the power rating of the overall converter. Rather, the main goal is to improve, in a controllable or active way, the power quality of the NPC bridge .

which may have a relatively low switching frequency. This enables superior closed-loop performance for medium-voltage NPC SHE-based schemes, where this modulation strategy has been selected for efficiency purposes. It also allows the use of smaller inductive filters when connecting to the utility supply in AFE applications. hence no changes are made to the power circuit and modulation stage of the NPC inverter, the series HB power circuit and its control scheme can be easily added as an upgrade to the existing NPC-driven applications. The proposed series HB filter control scheme can be used either as a grid or load interface, depending on whether the NPC converter is used as an AFE or an inverter, respectively. Both possibilities can be combined if used in a back-to-back configuration. The proposed floating dc-link voltage control scheme can be adapted to other hybrid topologies or CHB converters with the advantage that the isolated input transformers can be avoided.

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