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Hybrid Multilevel Inverter Configuration for Even and Odd Output Levels

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ABSTRACT

This paper presents comparative study and simulation results for different Hybrid Multilevel Inverter configurations. This paper covers hybrid multilevel inverters such as cascaded multilevel inverter with high voltage low-frequency pulse width-modulation (PWM) and low voltage high frequency pulse width-modulation (PWM) and series connected half-bridge modules hybrid multilevel inverters. Here the operating principle of each topology is discussed with a review of the relevant modulation method focusing mainly on total harmonic distortion (THD). Such multilevel inverters achieve higher power quality with a given switch count when compared to traditional multilevel inverters. The purpose of the circuits presented here is to minimize the reverse voltage stress that affects the power switches and decrease the harmonic distortion of the voltage applied to the load.

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Introduction

Hybrid multilevel inverters are receiving increasing attention for utility and drive applications. These are suitable for high and medium power applications. These are having ability to synthesize waveforms with better harmonic spectrum and attain higher voltages with a limited maximum device rating [1], [2]. In power electronics circuits a trade off in the selection of power devices in terms of switching frequency and voltage sustaining capability is observed [3]. Generally the voltage blocking capability of faster devices like Insulated Gate Bipolar Transistor (IGBT) and the switching speed of high voltage devices such as Integrated Gate Commutated Thyristor (IGCT) is limited [4]. Thus hybrid multilevel inverter topologies are studied for high and medium power applications in [5] – [10]. Other topology includes hybrid multilevel topologies based on the series connection of three-phase VSI or NPC with full-bridge modules which are proposed in [11], [12], [13]–[15] as alternative to the Cascaded Full-Bridge (CFB) inverters [16], [17]. Following the hybridization approach a multilevel inverter topology has been introduced in [18]. This hybrid topology utilizes a three-phase inverter with its output terminals connected in series to a pair, or multiple pairs (cascade), of half-bridge inverters connected with inverse polarity. Thus these two topologies are discussed in this paper along with simulation results for single phase configuration.

Working principle of hybrid multilevel inverters

The topology presented in reference [9] combines a Gate Turn-Off (GTO) thyristor based inverter and IGBT inverter similar to that shown in Fig 1.

This is based on the binary configuration of the voltage sources, meaning that this circuit can synthesize 2^{N+1} -1 levels on the load voltage, N being the number of dc sources. The upper full-bridge is composed by switches of high voltage blocking capability and therefore of low operation frequency (GTO for instance), while the bottom full-bridge is switched at high frequency, but with lower rated voltage (IGBT as an example). Using an appropriate modulation strategy it is possible to synthesize a seven-level voltage waveform: -3E, -2E, -E, 0, E, 2E and 3E. The output voltage wave shape for this circuit is shown in Fig.2.

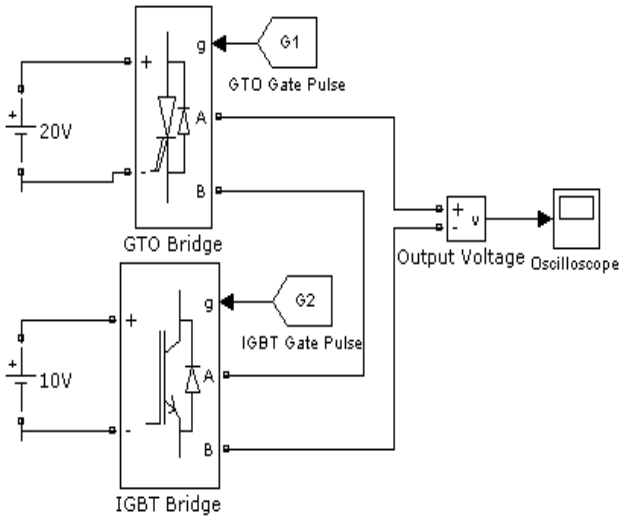

Fig 1. Asymmetrical Hybrid Multilevel Inverter

In Fig 3. hybrid multilevel inverter employing half-bridge modules and a single phase inverter is described. In this configuration the power ratings for insulated dc sources is reduced. This allows unidirectional power flow in all dc sources for any modulation index. Also it lowers the power demand on the insulated dc sources for high modulation indexes. Hence input current harmonics are minimized. Phase and line voltages obtained are with low THD. Fig.4 shows output for four level output voltage.

Modulation techniques used for various topologies

The modulation strategy includes the hybrid modulation concept, which is based on the unique pulse modulation together with the sinusoidal pulse width modulation (SPWM). Under this modulation strategy, the slow switches are modulated to commutate at the fundamental frequency, while the fast switches commutate at a higher frequency. As a result of that, there is an improvement in the output wave shape quality. Then, the spectral response of the output voltage depends on the fast switches, while the whole capacity of voltage generation relies on the slow switches [1].

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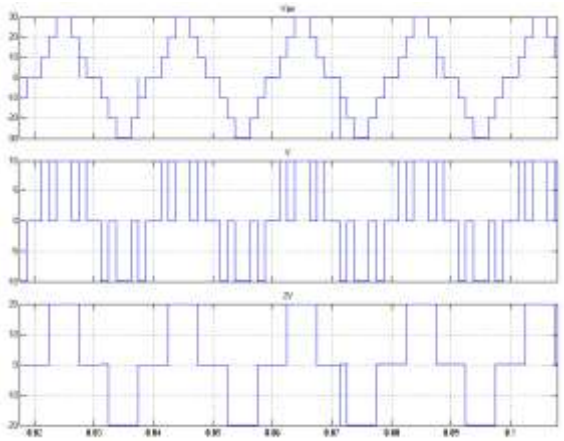


Fig 2 Output Voltage Wave Shape

Modulation schemes can be conventional modulation or hybrid modulation scheme for hybrid multilevel inverter employing half-bridge modules.

This section presents a modulation scheme for the four-level operation of the half-bridge modules where the switching is done at high modulation indexes. The half-bridge modules are derived from sinusoidal modulating signals (ref) compared to three synchronized triangular carriers. The switches are driven by the compared output. The logic employed to generate the modulation pattern is presented in Fig. 6

The Phase Shift modulation pattern, applied in the proposed inverter, allows that all switches have the same conduction and switching losses.

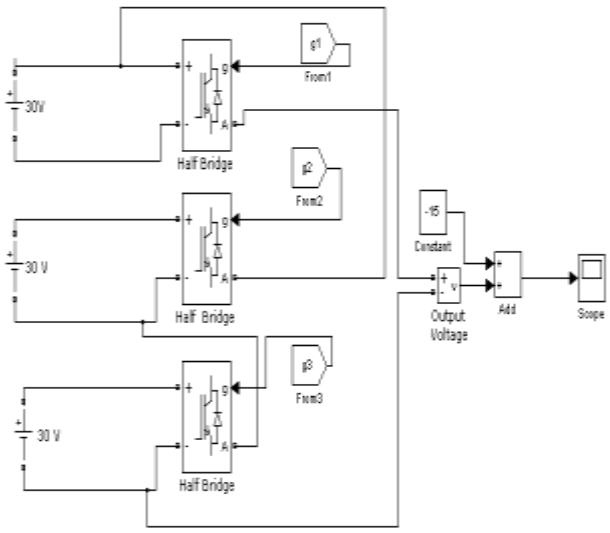


Fig 3. Single Phase Half Bridge Module

Simulation Results

It may be easily verified that with a combination of 20 V and 10 V in this topology, it is possible to synthesize output voltage levels to seven levels and those are 30 V , 20V , 10 V, 0V , -10V, -20V, -30V at phase leg output.

In single phase half bridge hybrid multilevel inverter output levels obtained are even number i.e four levels in this topology.

Simulation results for both hybrid multilevel inverters are shown as below. Also FFT analysis is done with high carrier frequency and reference at 50Hz.

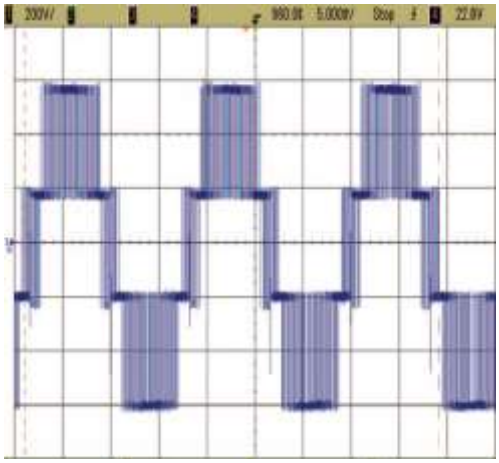


Fig 4 Output Phase Voltage

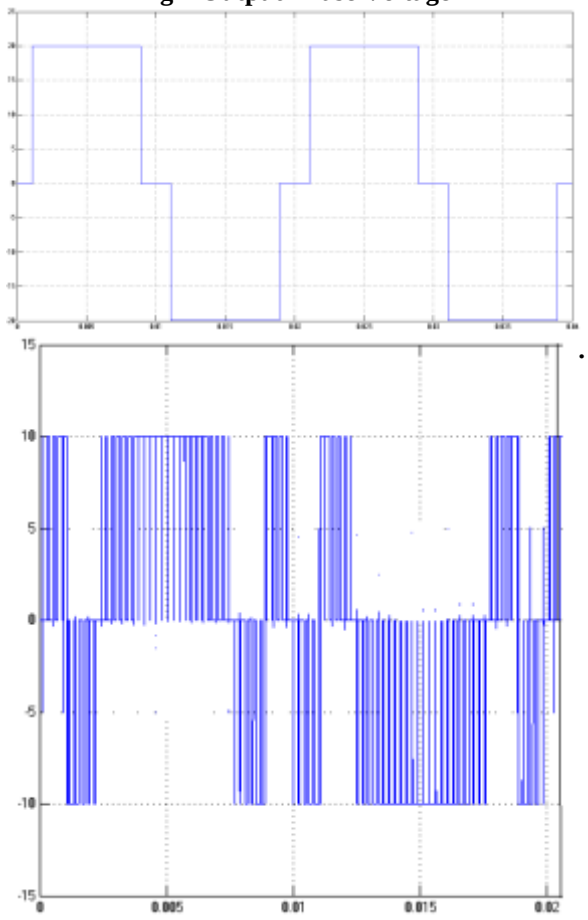
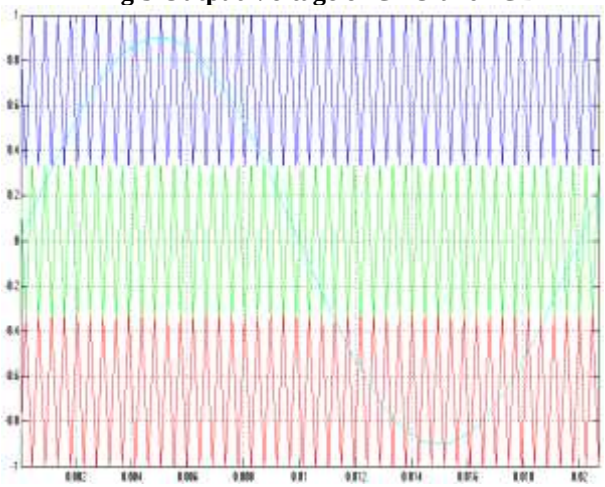


Fig 5 Output Voltage of GTO and IGBT



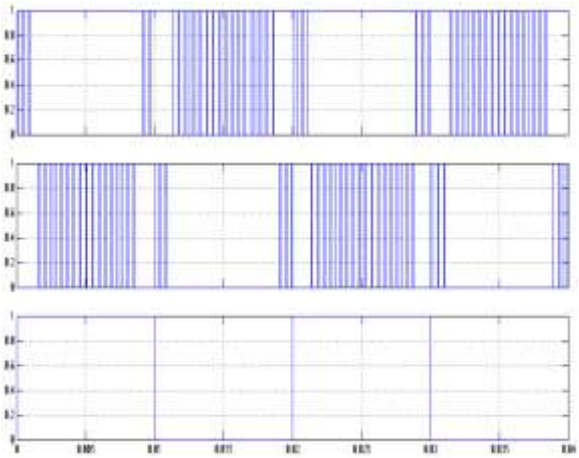


Fig 6 Reference and Carrier for Half Bridge Module

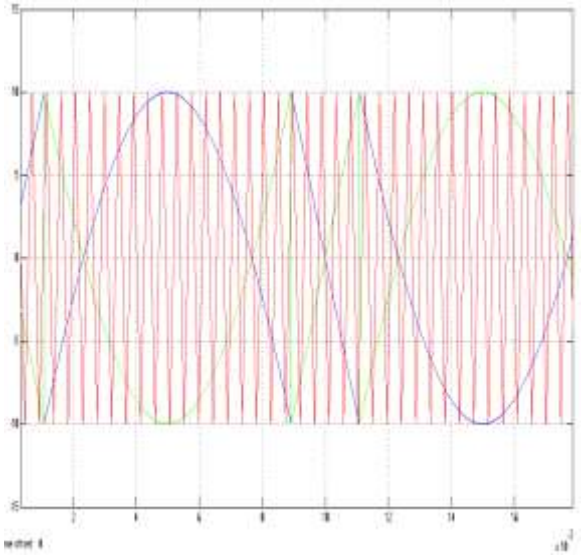


Fig 7 Hybrid Modulation Technique

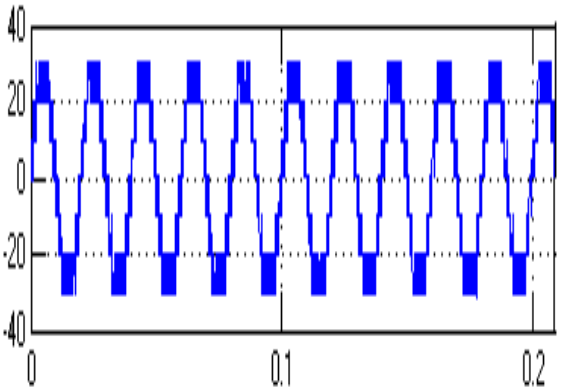


Fig 8 Seven Level Simulated Output Voltage

Conclusion

This paper presents brief over view of how different modulation techniques can be used to generate different multilevel outputs where levels are not equal. It is observed that by varying frequency of carrier total harmonic distortion (THD) changes. Also THD has variation with the modulation strategies applied.THD as low as 0.79% can be achieved using hybrid multilevel inverter in asymmetric configuration i.e. using different power devices with different switching frequency. While using single phase for half bridge module THD achieved as low as 1.84% with high modulation index modulating technique.

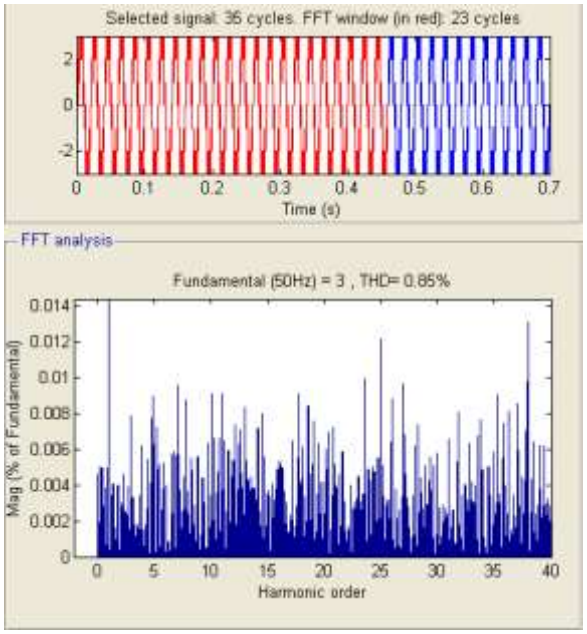


Fig 7 Output Voltage at 35 Cycles and THD=0.85% at 23 Cycles

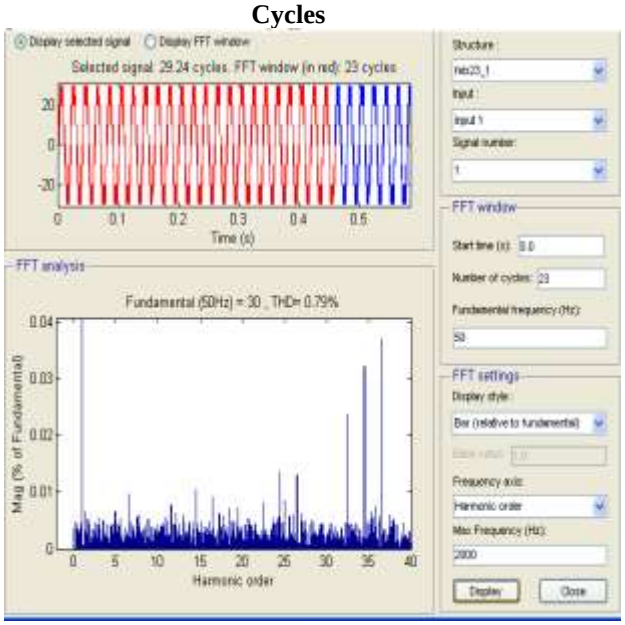


Fig 8 Output Voltage at 29.24 Cycles and THD=0.79% at 23 Cycles

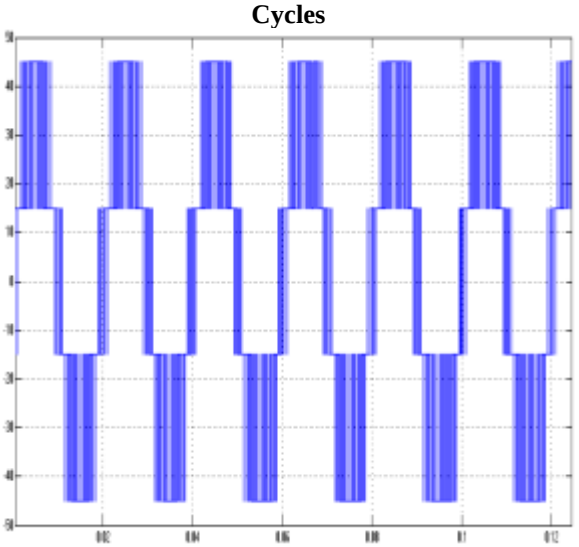


Fig 9 Four Level Simulated Output Voltage

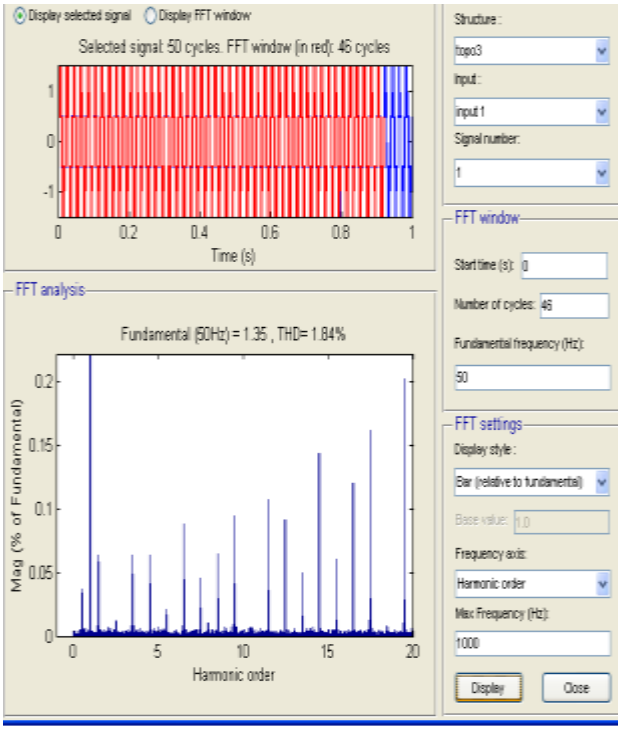


Fig 10 Output Voltage at 50 Cycles and THD=1.84% at 46 Cycles

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