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A review and comparative study of hybrid multilevel inverter configuration

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ABSTRACT

This paper presents comparative study of Hybrid Multilevel Inverter in continuation to previous paper. Different distinct topologies of multilevel inverters for power circuits used in Hybrid Multilevel Inverter are discussed. The comparison is done with respect to different performance index like switching devices, power applications and modulation techniques used. Different topologies are discussed and reviewed in brief.

Introduction

From previous paper this paper is extended to discuss other hybrid multilevel inverter topologies, considering additional design specifications, efficiency and other issues. Multilevel power conversion has been receiving increased attention in the past few years for high-power applications [1]. Numerous topologies and modulation strategies have been introduced and studied extensively for utility and drive applications in the recent literature. These inverters are suitable in high-voltage and high-power applications due to their ability to synthesize waveforms with better harmonic spectrum and higher voltages with lower maximum device rating. In the family of multilevel inverters, topologies based on series-connected H-bridges are particularly attractive because of their modularity and simplicity of control. It gives high flexibility to extend inverter to more legs or high number of level which minimize total harmonic distortion (THD) that can provide reduction of output filters.

Working principle of hybrid multilevel inverters

Hybrid multilevel inverter gives multi level operation by using hybrid source, hybrid configuration or hybrid device in such a way to produce output with advantages mentioned above then such topologies are known as hybrid multilevel inverter (HMLI). Broadly HMLI can be classified as per power circuit configuration and modulation technique used. In this paper discussion is as per power circuit.

Out of many topologies here four topologies are discussed: i) Hybrid Multilevel Inverter Based on Main Inverter and Conditioning Inverter [2]. ii) Hybrid multilevel inverter employing half-bridge modules and a three-phase inverter [3]. iii) Hybrid Cascaded Multilevel Inverter with single dc source [4]. iv) Hybrid Clamped Multilevel Inverter [5].

Various topologies and their comparison

In this section different hybrid multilevel inverter topologies are compared in brief.

Hybrid multilevel inverter based on main inverter and conditioning inverter consist of the Neutral Point Clamped (NPC) and the cascaded H-bridge topology combined into a hybrid multilevel inverter. The cascaded H-bridge is supplied by separate DC sources (main Inverter) and the three-level NPC inverter is supplied by the floating ultra capacitors (conditioning inverter). The conditioning inverter just uses non-supplied ultra capacitors as its power source. The main and the conditioning inverters are in series as shown in Fig. 1 (a).

Because the conditioning inverter doesn't have power supply, its initial pre-charging process can't be accomplished in a classical manner. In order to avoid additional equipment, a special pre-charge method has been developed [6].

The braking energy can be stored in the conditioning inverter's floating ultra capacitors to improve the efficiency and performance of the system. Such configuration is applied where motors accelerating and braking occurs frequently. Generally modulation technique used is space vector modulation (SVM) and control method with the power management.

In Fig. 2 (a) hybrid multilevel inverter employing half-bridge modules and a three-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.

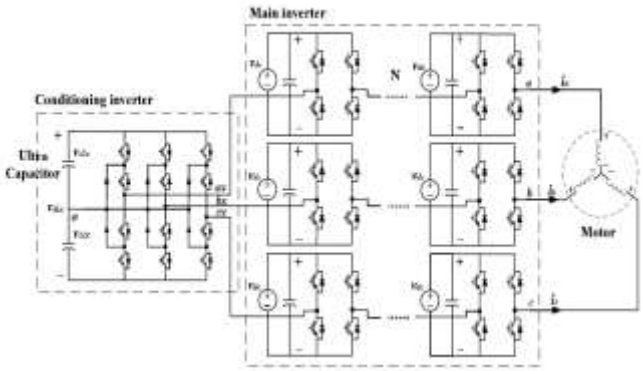

Fig 1 (a) Hybrid Multilevel Inverter Based on Main Inverter and Conditioning Inverter

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. Modulation schemes can be conventional modulation or hybrid modulation scheme [7]. Another hybrid cascaded multilevel inverter includes a standard full bridge 3-leg

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inverter (one leg for each phase) and an H-bridge in series with each inverter leg. It can use only a single DC power source to supply a standard 3-leg inverter along with three full H- bridges supplied by capacitors or batteries as shown in Fig 3(a). In this HMLI the capacitor's voltage regulation control method consists of monitoring the output current and the capacitor voltage so that during periods of zero voltage output, necessary capacitor is charged or discharged with opening or closing of proper switches. PWM and fundamental frequency switching methods can be used for the hybrid multilevel inverter for attaining the above mentioned task. Multilevel carrier based PWM method is used to produce a five level phase voltage.The inverter can be used in electric vehicles (EV) / hybrid electric vehicles (HEV) to drive electric motor. The hybrid cascaded multilevel inverter can be used for utility interface like solar grid application. Such configuration increases the power density [8].

Insertion of the dead time between the complementary switching devices is necessary but that causes "dead-time effect", which means output waveform distortion, the increase of the output harmonics content and degradation of static or dynamic performance. The causes of the dead time effect are: (1) two adjacent carrier cells (triangle waveform) are corresponding to two different switching devices(2) the rotation shift of the arranged sequence of the carriers occurs at the edge of the two kinds of carrier waveforms corresponding to the different switching devices.

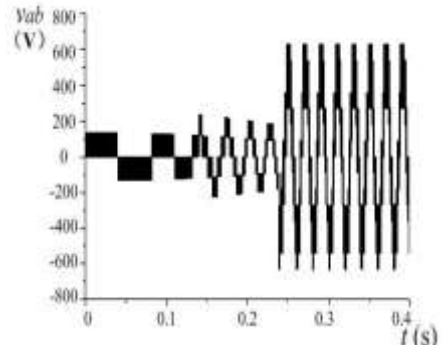

Fig 1(b) Hybrid Multilevel Inverter Based on Main Inverter and Conditioning Inverter

A hybrid clamped multilevel inverter topology with self voltage balancing is presented in [18]. Fig. 4 (a) shows one leg of the five-level topology. The main switching devices Sa1, Sa2, Sa3 and Sa4 are complementary with Sa1', Sa4', Sa3' and Sa2' respectively, and Sa1 is complementary with Sac1.

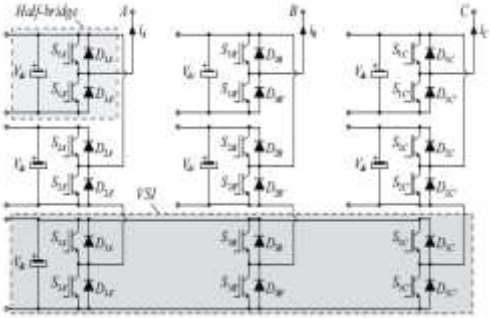

Fig 2(a)Hybrid multilevel inverter employing half-bridge modules and a three-phase inverter.

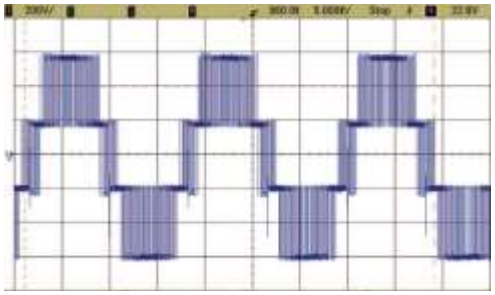

Fig 2(b)Hybrid multilevel inverter employing half-bridge modules and a three-phase inverter.

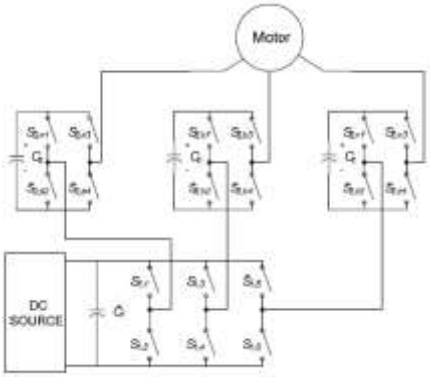

Fig 3.a) Hybrid Cascaded Multilevel Inverter with Single dc Source

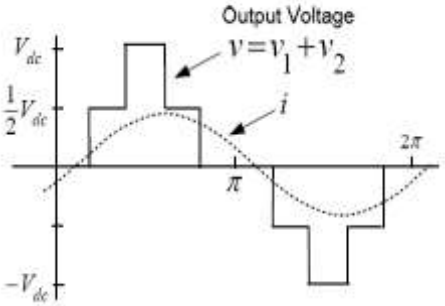

Fig 3(b) Hybrid Cascaded Multilevel Inverter with Single dc Source Output Waveform

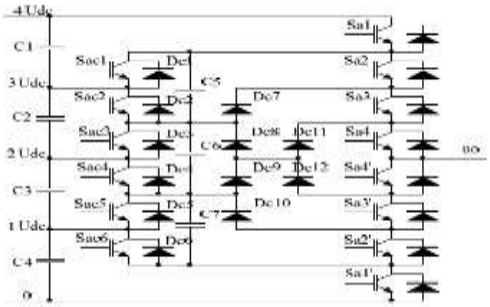

Fig. 4 a) Hybrid Clamped Multilevel Inverter.

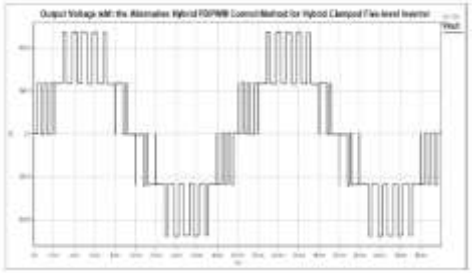

Fig. 4 b) Hybrid Clamped Multilevel Inverter Output Voltage

Among the clamping switching devices Sac1-Sac6, the adjacent switching devices are complementary. Self-voltage balancing in capacitors is realized by changing from one kind of device switching mode combination to another by turns. A novel AHPWM (Alternative Hybrid PWM) method for hybrid clamped multilevel inverters is used. It can completely eliminate all the unwanted output [9] and [10].

Conclusion

Hybrid Multilevel Inverter Based on Main Inverter and Conditioning Inverter topology is very suitable for the applications which need motors accelerating and braking frequently. The braking energy can be stored in the floating ultra capacitors of conditioning inverter to improve the efficiency and performance of the system.

Hybrid multilevel inverter employing half-bridge modules and a three-phase inverter is able to provide better losses distribution among the power semiconductors and to limit the maximum device loss to a lower level when compared to a fully high frequency switched inverter. In this case devices are replaced with lower speed and lower forward voltage drop IGBTs for the four-level hybrid inverter which is able to achieve higher efficiency figures.

In third and fourth topology capacitor voltage balancing is of importance.

Third topology generally used for HEV and EV applications. While Hybrid Clamped Multilevel Inverter reduces filter size.

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