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BINARY HYBRID 31-LEVEL MULTILEVEL INVERTER WITH REDUCED NUMBER OF SWITCHES

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Abstract:

A binary hybrid 31-level multi-level inverter is proposed in this paper for medium voltage applications, and compared with a conventional cascaded H-bridge inverter. The main drawback of conventional topology is a large number of power supplies and semiconductors required to generate these multistep voltage waveforms. Due to the hybrid structure inverter, 31 levels can be manufactured with the fewest number of components, as only 12 switches were used. As the number of output voltage levels increases, the proposed architecture reduces the number of IGBTs and gate driver circuits significantly. The proposed inverter can generate high-quality output voltage close to the sine wave. The circuit of the hybrid inverter and cascaded H-bridge inverter was simulated using the MATLAB program. A fast Fourier transform analysis of the output voltage waveforms was performed, which resulted in a total harmonic distortion value of 3.60% in the hybrid inverter while the total harmonic distortion value was in the bridging modulator. 3.74%.

Keywords: Multilevel-Inverter (MLI), Cascaded H-Bridge multilevel inverter (CHB-MLI), Total harmonic distortion (THD), Hybrid Multilevel inverter (HMLI).

1. INTRODUCTION:

In high-power applications, multilevel inverters (MLI) are becoming more popular than two-level inverters [1] [2]. Conventional two-level inverters require a high switching frequency to produce a quality output voltage waveform, whereas MLI can produce more power by combining several power switches with multiple low voltage dc sources [3][4]. All switches in multilevel inverters are connected in series, allowing them to operate at higher voltage levels [5]. MLI has several advantages, including high voltage capability, low switching losses, low DV/DT, less THD, and lower electromagnetic compatibility [6][7].

The neutral point converter, flying capacitor, and cascaded H-bridge multilevel inverter are the three main MLI configurations [8] [9]. CHMI has more benefits than the other two mentioned. CHMI Cascaded H-bridge multilevel inverters, as shown in the figure (1), have gotten a lot of attention because of their advantages like low component count which lacks flying capacitors and clamping diodes., reliability, and modularity [10]. To obtain a sinusoidal output voltage wave, multilevel inverters can increase the number of output voltage levels. It will, however, necessitate more components, increasing the complexity

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and cost. To overcome the disadvantages listed above, a hybrid multilevel inverter derived from a cascaded H-bridge inverter is used [11] [12].

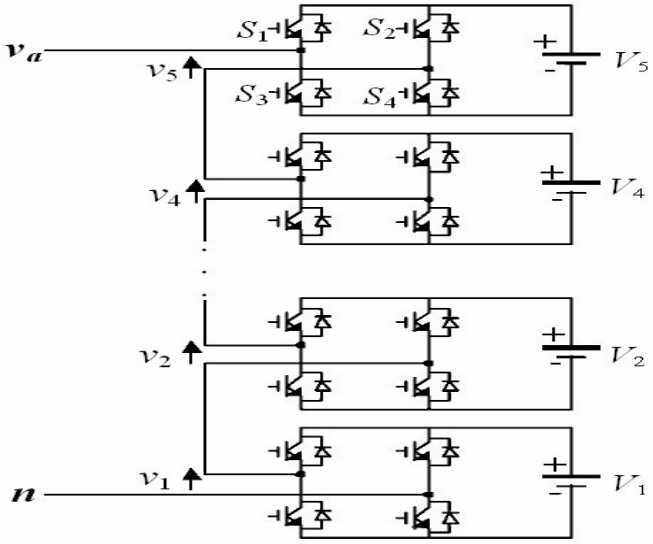

Figure (1): structure of cascaded H-Bridge

2. MODULATION METHOD:

When it comes to multilevel voltage source converters, the first thing that comes to mind is the requirement for a large number of switches, which can result in a complex pulse-width modulation (PWM) switching scheme [13].

Modulation is the process of turning on and off the power electronic switches of an inverter in a specific sequence to achieve a nearly sinusoidal waveform [14]. Modulation techniques are classified based on the switching frequency, as shown in Figure.2.

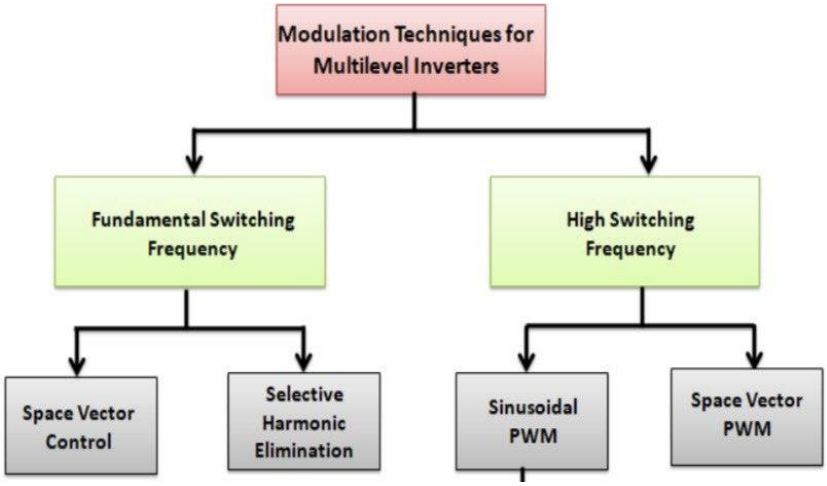

Figure (2): classification of Modulation Techniques

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Fundamental switching frequency techniques require only one of two power semiconductor switch commutations per output voltage cycle [15][16]. In a Sinusoidal PWM technique, a single sine wave is compared to a triangular (carrier) wave to generate pulses for an inverter's switching operations. By using a larger number of carriers, a sine PWM technique has been extended to multi-level inverter modules [17]. As a result, it is simply known as multi-carrier pulse width modulation. Multi-carrier-PWM (MCPWM) is the most common and simple switching scheme for multilevel voltage source converters [18] [19]. For an n-level inverter, (n-1) carrier waves are required. Each carrier signal is continuously compared to the voltage reference as shown in Figure.3 [20]

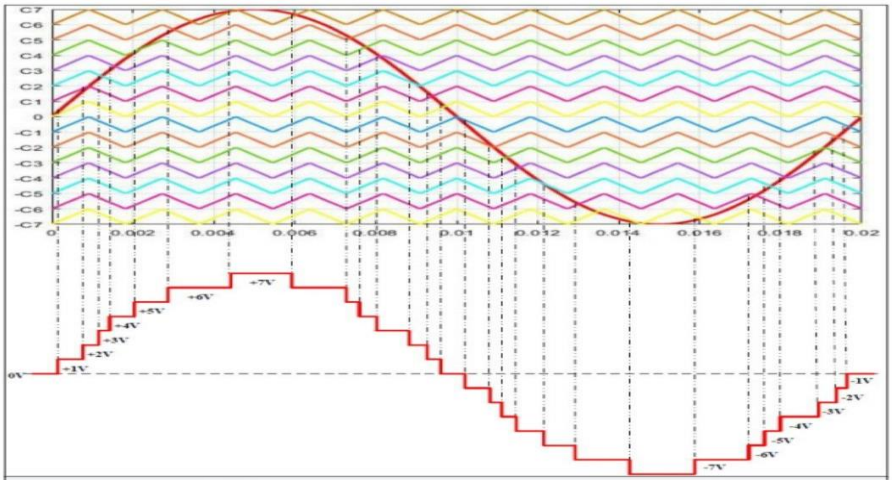

Figure (3): Generalized stepped waveform by using (MC-PWM)

Multicarrier-PWM technology can be divided into two parts: Level shift-PWM and Phase Shift-PWM LSPWM is again divided into three types [21] [22]. They are:

1. Phase Disposition-PWM (PD-PWM)
2. Phase Opposition Disposition-PWM (POD-PWM)
3. Alternate Phase Opposition Disposition-PWM (APOD-PWM).

This paper describes a Hybrid multilevel inverter that employs a binary dc input source and a minimum number of switching devices [24]. As a result, control is simplified and straightforward. In addition, MATLAB embedded function for constant voltage and constant frequency operation is written.

The conventional topology has four switches in an H-bridge unit, but the proposed topology has only two switches in an H-bridge unit [25]. As a result, the number of keys used will be halved leading to control being simplified, easy, and economic [26]. Switching losses are also significantly reduced. Figure 4 depicts a basic concept for generating output voltage levels where Vdc1=VDC, Vdc2= 2VDC, Vdc3= 4VDC, Vdc4=8VDC.

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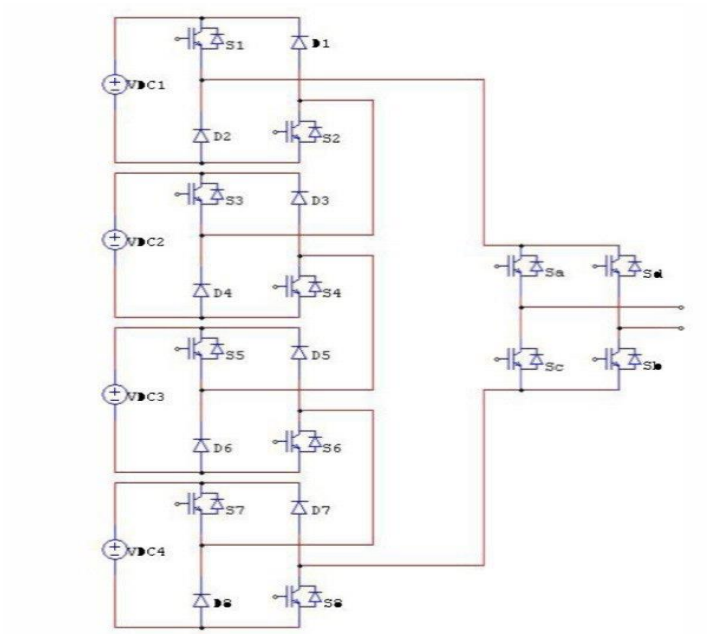
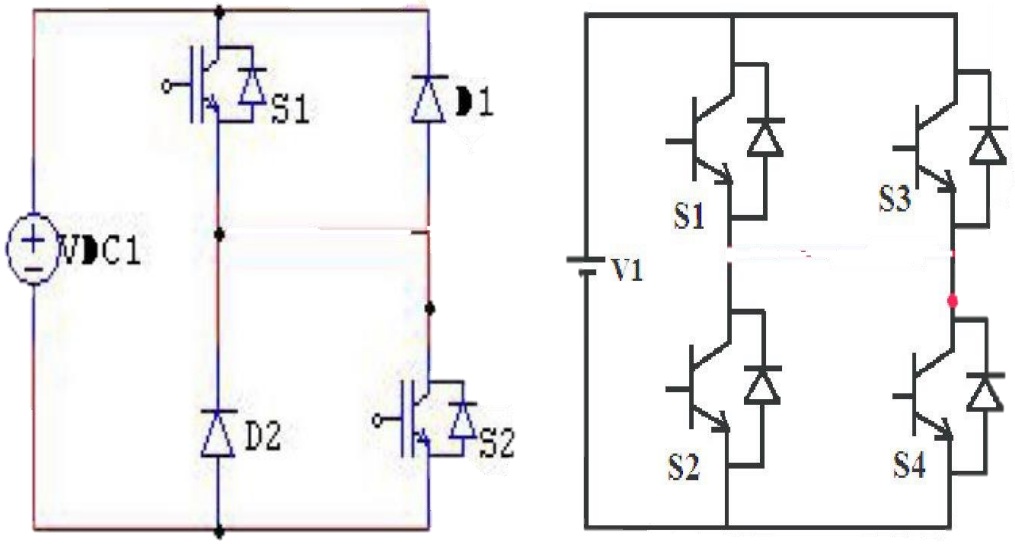


Figure (4): Proposed Hybrid topology for 31 levels

3- HYBRID MULTILEVEL INVERTER TOPOLOGY WITH THE FEWEST SWITCHES



a b

Figure (5): Basic unit of MLI. (a) Conventional cascaded H-bridge topology (b) Proposed Hybrid topology.

Figures 5(a) and 5(b) show the basic unit of a multilevel inverter in the conventional cascaded H-bridge and proposed hybrid topologies, respectively. The conventional cascaded H-bridge topology has four switches in an H-bridge unit, whereas the proposed

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Hybrid topology has only two switches in an H-bridge unit. As a result, the number of switches is reduced by half, as are the gate driver circuits. As a result, control is simplified, easy, and cost-effective. Switching losses are also significantly reduced.

Table 1: conventional topology with switching patterns

S1&S2	S3&S4	V_O
1	0	$+V_{DC}$
0	1	$- V_{DC}$

Table 2: conventional topology with switching patterns

S1&S2	V_O
1	$+V_{DC}$
0	$- V_{DC}$

Tables 1 and 2 show the switching scheme and output voltage for the conventional and proposed topologies, respectively. When (S1& S2) is turned on, the output voltage is +VDC, and when (S3 &S4) is turned on, the output voltage is -VDC. In the proposed topology, when (S1 &S2) is turned on, the output voltage is +VDC, and when they are turned off, the output voltage is -VDC, provided the diodes (DI&D2) are connected to a higher potential. As a result, the proposed topology allows for the distribution of DC voltage sources in a binary pattern.

The topology employs a binary dc input source. By using VDC, 2VDC, 4VDC, 8VDC it can synthesize 31 output levels: VDC, 2VDC…….14VDC, 15VDC as shown in table 3.

Table3: Conventional Topology with Switching Patterns

S8	S7	S6	S5	S4	S3	S2	S1	V
0	1	0	1	0	1	0	1	0
0	1	0	1	0	1	1	1	1
0	1	0	1	1	1	0	1	2
0	1	0	1	1	1	1	1	3
0	1	1	1	0	1	0	1	4
0	1	1	1	0	1	1	1	5
0	1	1	1	1	1	0	1	6
1	1	0	1	0	1	0	0	7
1	1	0	1	0	1	0	1	8
1	1	0	1	0	1	1	1	9
1	1	0	1	1	1	0	1	10
1	1	0	1	1	1	1	1	11
1	1	1	1	0	1	0	1	12
1	1	1	1	0	1	1	1	13
1	1	1	1	1	1	0	1	14
1	1	1	1	1	1	1	1	15

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Simulation results:

A 31-level inverter model in MATLAB/Simulink has been created the total harmonic distortion is used to evaluate the quality of the output voltage waveform (THD).

Figure 6 depicts the MATLAB/Simulink model of the proposed topology. Figures 7 and 8 show the simulation results for output voltage, and total harmonic distortion

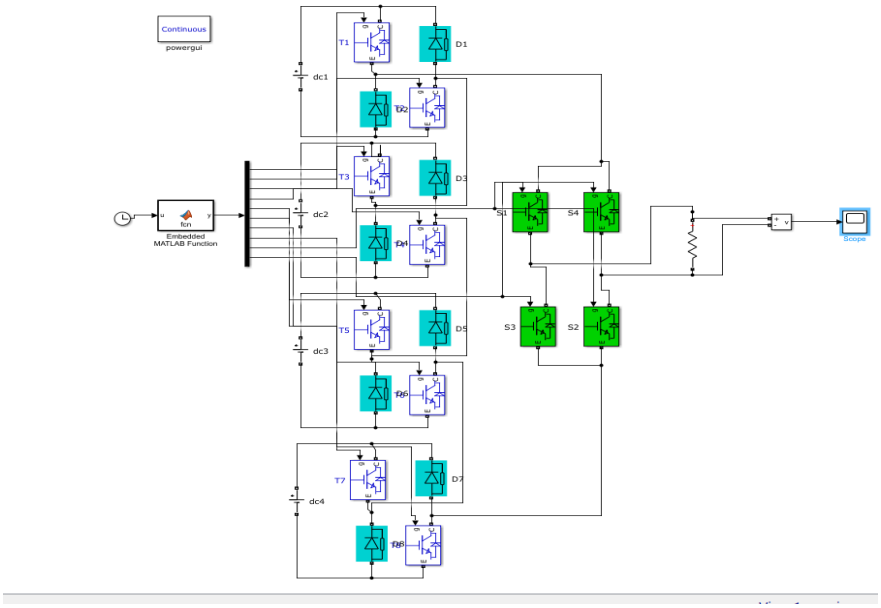

Figure (6): MATLAB/Simulink Model of Proposed Hybrid Multilevel Inverter

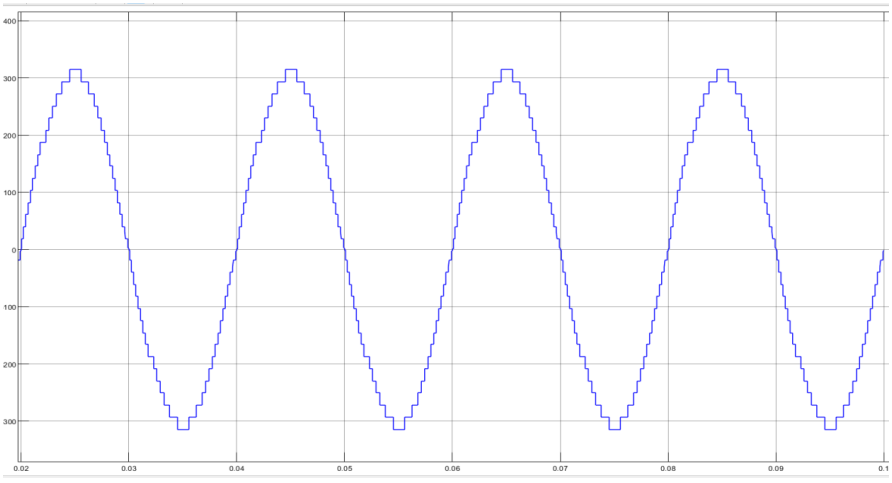

Figure (7): Output Voltage for 31 Levels

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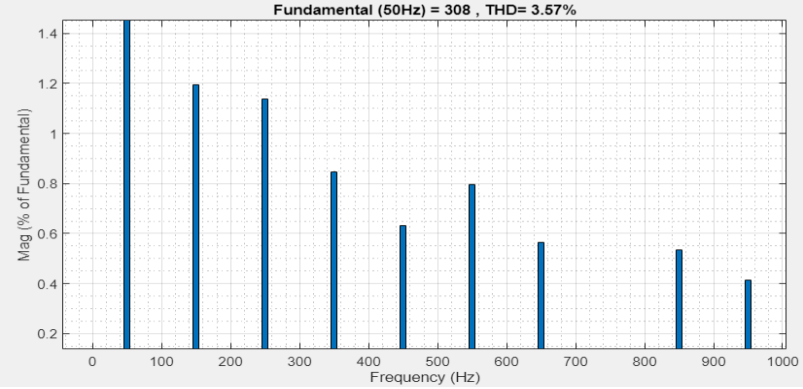

Figure (8): THD% of voltage waveform of 31 level in proposed Hybrid multilevel inverter

While the simulation results of the cascade H-bridge multi-level inverter to generate 31 levels using the multi-carrier pulse width modulation technique were as shown in the following figures:

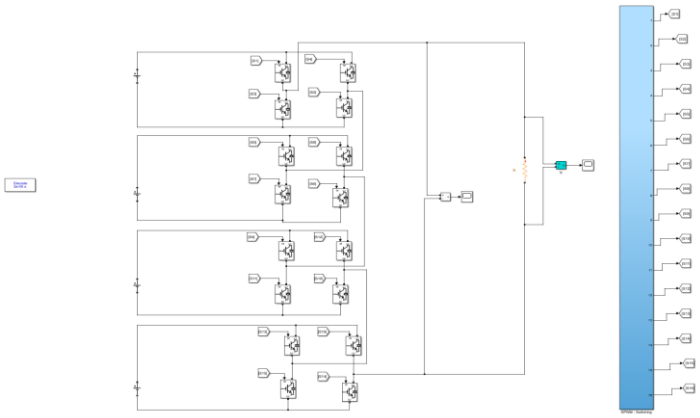

Figure (9): simulation model of 31 Level-Cascaded H-Bridge inverter

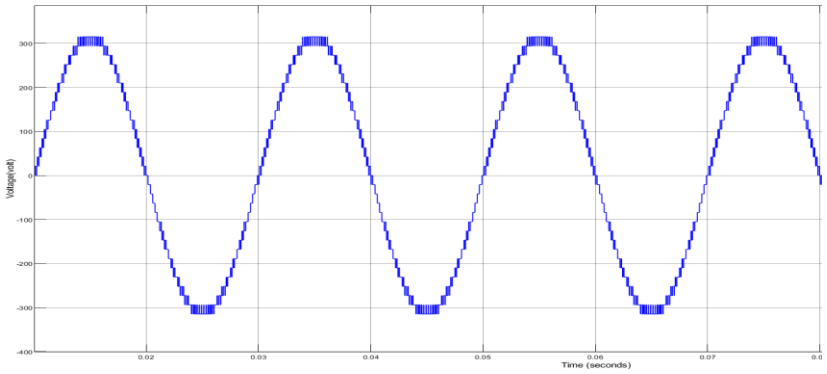

Figure (10): output voltage for 31 levels

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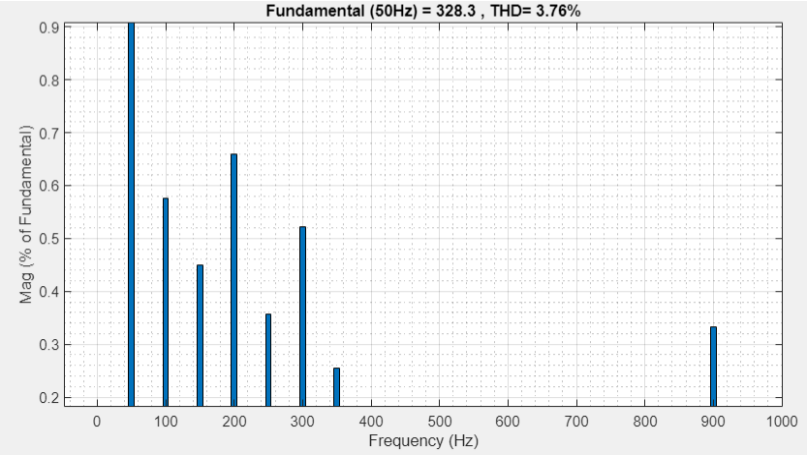

Figure (11): THD% of voltage waveform of 31 levels in proposed hybrid MLI

Table (2): comparison between cascaded H-Bridge and Hybrid multilevel inverter to generate 31-level

Type of Typology	Number of switches	THD%
Hybrid MLI	12	3.60%
Cascaded H-bridge MLI	16	3.76%

4. CONCLUSION

For the multilevel converter, a new multilevel module (MLM) has been proposed. The proposed topology combines MLMs and full-bridge converters. The proposed Hybrid topology increases flexibility in design and the converter's capability to be optimized for various goals. Cascaded H-bridge topologies have been compared to the proposed Hybrid topology. It has been demonstrated that the proposed Hybrid topology provides 31 output voltage levels using 12 IGBTs. While, the Cascaded H-Bridge topology generates 31 voltage levels with 16 IGBTs. The proposed topology not only has fewer switches and components than the alternative. The proposed topology may be a good solution for applications that require high power quality or a large number of dc voltage sources. The proposed topology's operation and performance have been validated using computer simulation. Analyses and simulations demonstrated the proposed system's superiority.

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