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A 15-Tiered Multi-Level Inverter Designed for Use in PV and HEV Applications

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Abstract:
The basis of this project centers around different topologies and the cascaded H bridge inverter. The primary application of inverters is for businesses and manufacturing needs. The multilevel inverter's distinct arrangement results in decreased output voltage harmonics. Multilevel inverters come in various variations. Cascaded multilevel inverters have acquired a lot of attention in the power industry due to their demand for fewer components. When the level count rises, the harmonic components in the voltage waveform output decline. The inverter with fifteen levels constructed in a cascaded H-bridge configuration utilizes the fewest possible switches. The waveform generated through synthesis becomes more like the desirable waveform as the level rises due to the increasing number of steps producing a staircase wave. By using a small number of switches, the issue of switch losses and power losses can be completely resolved.

SECTION I INTRODUCTION

Photovoltaic cells have the ability to convert solar energy, easily accessible and affordable, into electricity [1]. Solar panels generate electricity that is in the form of direct current (DC), while the current electricity system and electric devices use alternating current (AC). Inverters, also known as DC/AC power converters, are utilized to convert solar panel electricity into a usable form. Traditionally, the utilization of two level inverters was common for the integration of solar systems into the grid [2]. Despite their usefulness, these inverters produce fluctuating signals of electric current and voltage at their outputs, which necessitates the use of filters in order to obtain pure sinusoidal waveforms with fundamental frequency. The energy in the higher harmonics is being wasted, making the process ineffective. Given the rising costs and declining efficiency of solar systems, it is imperative to create new, cost-effective methods of converting solar energy into electrical power. In the technical literature, between references [3] and [8], various designs of multilevel inverters have been put forth. The neutral point clamped or diode clamped [9], the flying capacitor or capacitor clamped [10], and the cascaded H-bridge [11] are the three basic multilevel topologies frequently mentioned. The use of neutral point clamped inverters was first suggested for operating motors. Compared to the fundamental frequency, they significantly decrease the amplitude of odd harmonics. The primary drawbacks of this structure are the imbalance of the voltage in the DC link capacitor and the need for a significant number of clamping diodes for a greater range of voltage levels. Topology designs that utilize clamped capacitors are used in transformer-less systems [12], but their reliability is diminished by the need for numerous electrolytic capacitors. H-bridge topologies arranged in a cascading manner are better suited for achieving a greater amount of voltage levels. In addition, they possess designs that are easily interchangeable and uncomplicated methods of control. However, they necessitate distinct DC power sources. Initially developed for applications requiring high power and voltage [13], multilevel inverters have more recently been utilized in low power systems, particularly those involving photovoltaic technology [6]-[14]. When compared to traditional inverters with two levels, multilevel inverters demonstrate better qualities. Multilevel inverters have output waveforms with fewer harmonics because they have more voltage levels, which means that the filter size can be reduced or eliminated completely. Due to switching at lower frequencies, multilevel inverters are more efficient because their switching losses are reduced. Additionally, by supplying a number of DC links, the use of multilevel inverters can facilitate modular designs. The ability to control DC link voltage separately makes them appropriate for use in solar applications and enables the tracking of the maximum power points of solar panels separately [6].

Multilevel inverters require a sizable number of power semiconductor switches in order to produce higher output voltage levels. Power switches cost more as a result of gate drivers and protective circuits being included. Many hybrid multilevel inverters have been created in attempt to address this problem, with the main goal being to obtain the largest number of voltage levels possible utilizing the fewest power semiconductor switches and supporting circuit components [15]-[20].

A detailed overview of the most important features of frequently used multilevel inverter configurations is given in [14]. We also propose a novel multi-transformer-based topology for stand-alone photovoltaic applications. However, transformer-based implementations can be expensive. Gupta et al. al., [15] compares topologies with reduced device count for traditional multilevel converters, and the reduced device count comes with many tradeoffs, such as higher power switch voltage ratings and loss of modularity. concluded. The authors of [17] and [18] proposed a new multilevel inverter topology with a reduced number of devices.

The proposed topologies are a hybrid of a full bridge converter and a modular sub multilevel converter. These topologies' primary flaw is the utilization of bidirectional power switches. Bidirectional power switches are expensive to implement and require complicated drive circuitry. The majority of multilevel topologies in use today assert that they lower the overall device count. Since the components of a multi-level inverter differ greatly in terms of cost and complexity this objective may be deceptive. The placement of diodes and capacitors in printed circuit boards is simple and they are inexpensive. On the other hand, power switches are pricey, and their operation necessitates the careful application of transistor gate drivers. In some applications of these power switches, additional components like snubbing networks and resonant circuits [2] might also be needed. Accordingly, when one opts for a practical implementation, an optimization for the reduced number of total devices as carried out may be deceptive and less useful. When looking for the best way to implement a multi-level inverter, it would seem more prudent to focus on some switches.

SECTION II

MULTILEVEL CASCADED INVERTERS

The cascade H-Bridge inverter is made up of a number of interconnected H-Bridges. A formula is given for calculating the number of DC sources required to generate the (2n+1) output voltage stages in a multilevel cascade inverter.

$$M = 2n + 1 \quad (1)$$

Where 'n' represents the required number of DC sources and M is number of output voltage levels. Output voltage is given as the sum of voltages of each single-phase H-bridge cell.

$$V_{an} = V_{dc1} + V_{dc2} + - - - - - V_{dc(n-1)} + V_{dcn} \quad (2)$$

The overall design of a single phase cascaded multilevel H-bridge inverter is portrayed in Figure 1. Every individual H-bridge or full bridge in one phase includes its own distinct DC source. A multilevel inverter with a cascaded structure produces five or seven output voltage levels, depending on whether it has two or three separate DC voltage sources. The output voltage levels range from Vdc to -3Vdc for the seven-level inverter and from Vdc to -2Vdc for the five-level inverter. Figure 1 indicates that every individual phase full bridge includes four switches, namely S11, S12, S13, S14, which produce three levels of output voltage: Vdc, 0, and -Vdc. The series structure of the cascade multilevel inverters allows for scalability and provides an advantageous circuit layout, making switching redundancy possible. These inverters are limited to specific uses because they require specific DC voltage sources.

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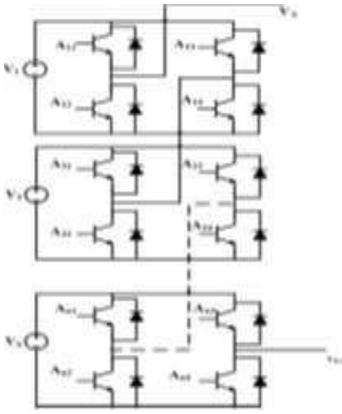


Fig 1: common structure of cascaded multilevel inverter

Switching states												Output voltage
P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	
1	1	0	0	1	1	0	0	1	1	0	0	7Vdc
0	1	0	1	1	1	0	0	1	1	0	0	6Vdc
1	1	0	0	0	1	0	1	1	1	0	0	5Vdc
0	1	0	1	0	1	0	1	1	1	0	0	4Vdc
1	1	0	0	1	1	0	0	0	1	0	1	3Vdc
0	1	0	1	1	1	0	0	0	1	0	1	2Vdc
0	0	1	1	1	1	0	0	0	1	0	1	Vdc
0	1	0	1	0	1	0	1	0	1	0	1	0Vdc
1	1	0	0	0	0	1	1	0	1	0	1	-Vdc
0	1	0	1	1	1	0	0	0	1	0	1	-2Vdc
0	0	1	1	0	0	1	1	0	1	0	1	-3Vdc
0	1	0	1	0	1	0	1	0	0	1	1	-4Vdc
0	0	1	1	0	1	0	1	0	0	1	1	-5Vdc
0	1	0	1	0	0	1	1	0	0	1	1	-6Vdc
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fig 2: Sample Switching Table of 15-MULTI LEVEL INVERTER

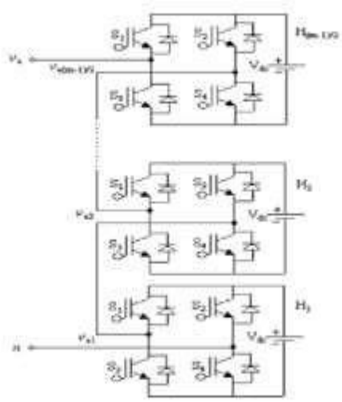


Fig 3: Cascaded H-Bridge 15 level Muti level Inverter

The modified H-bridge topology serves as the basis for the proposed topology [9]. The suggested design cuts down on the amount of DC voltage sources and switches needed, as compared to traditional cascaded multilevel inverters. In this work we proposed new topologies for 9-level, 11-level, 13-level and 15-level inverters. The presented inverters are all originated from a 7-level inverter. The 7-level inverter with adjusted H-bridges is illustrated in Figure 2. The composition of this arrangement includes half a dozen power switches and two DC voltage sources that are not the same in size. If the DC voltage sources have matching values, the amount of output voltage levels will be reduced, so in order to produce more levels, there needs to be difference in the magnitudes of the voltage sources. To generate a k-level staircase waveform for Vbus, k power switches are necessary in the topology being suggested. To achieve a Vac waveform with 2k + 1 levels, four extra switches are employed in the H-bridge inverter. As far as we know, you can create a staircase voltage alternating current waveform with 2k + 1 levels using only k + 4 power switches, k capacitors, and k diodes. This requires fewer devices than the current multilevel topology.

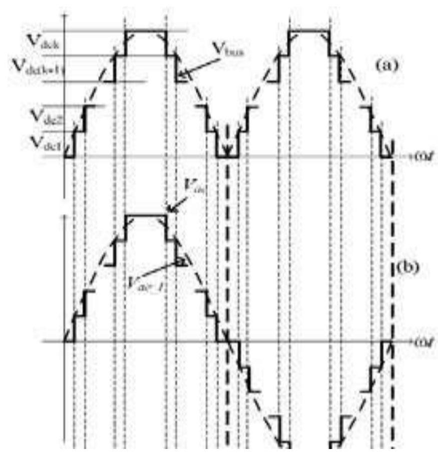
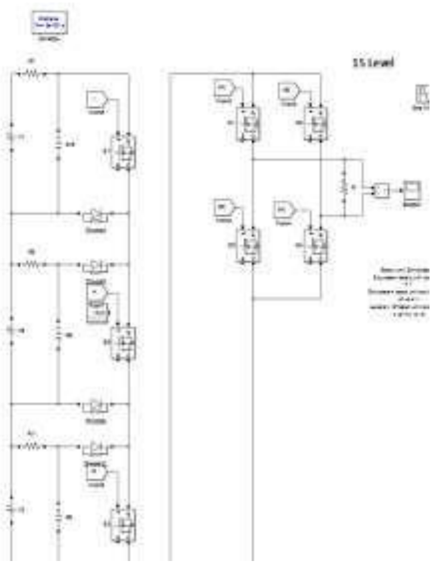


Fig 4: Output waveform and states of various switches

It is important to note that the H bridge in our design necessitates the use of four switches with a significant voltage rating. In contrast to standard diode-clamped and cascaded H-bridge designs, where all the switches have similar low voltage ratings, this approach is different. Even though the voltage rating of a switch has a direct impact on its cost, the essential driver circuits usually do not change. Our suggested structure still provides a noteworthy benefit when it comes to cost and ease of implementation.

Simulation Circuit & wave form:



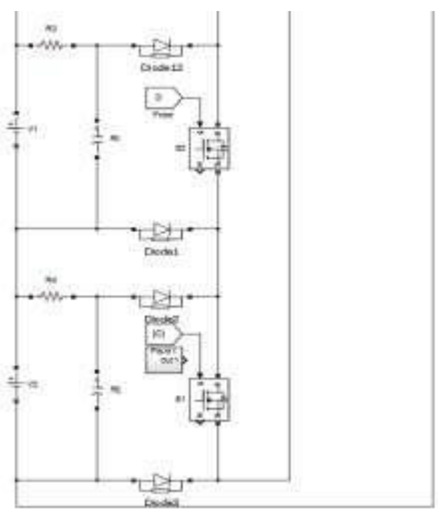


Fig 5: simulation Diagram of Multilevel Inverter Topology

Controller Diagram:

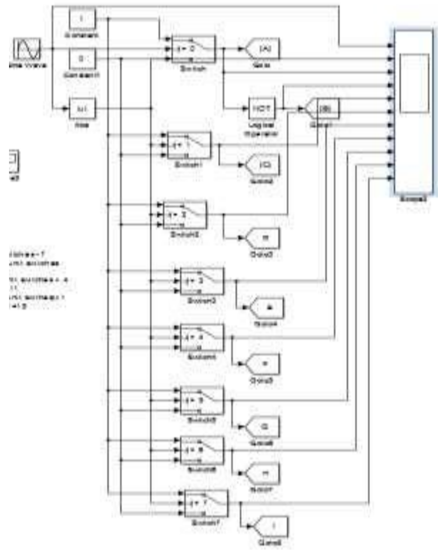


Fig 6: CONTROLLER of Cascaded H Bridge Multilevel

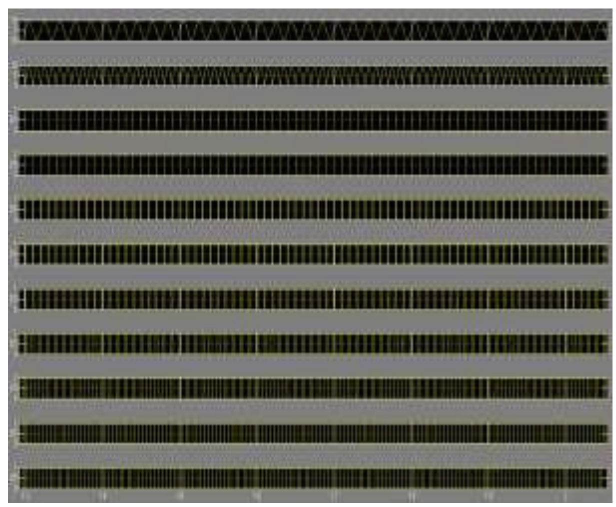


Fig 7: Switching waveforms CHM

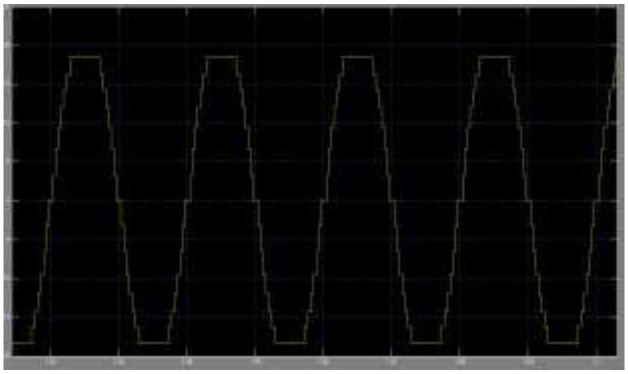


Fig 8: 15-level Multilevel Inverter waveform

SECTION III

HARDWARE MODEL

In the lab, a prototype hardware model of the 15-level inverter has also been constructed. The kit is shown in the figure 8.

Fig 8: Hardware model

Fig 9: Waveforms of 15-level output voltage

CONCLUSION

A recently suggested structure of multilevel inverter has been introduced. The suggested structure is a mixture of traditional diode clamped and H-bridge converters. In cases where there are several distinct sources of DC power, it may be beneficial to use this option for solar power applications. The proposed topology's concept and working principles were shown in this paper. To confirm the benefits of the new circuit, a comprehensive evaluation regarding efficiency and real-world application is still necessary.

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