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A Novel 15-level Multi-level Inverter for PV and HEV Applications

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Abstract:

This project is based on cascaded H bridge inverter and various topologies. Inverters are mainly used for commercial and industrial purposes. The unique structure of the multilevel inverter is low harmonics in output voltage. There are different types of multilevel inverters. Among these Cascaded multilevel inverters drawn tremendous interest in power industry because it requires less number of components. As the number of level increases the harmonic content of output voltage waveform decreases. This Cascaded H-Bridge fifteen level inverter with minimum number of switches. As the level increases the synthesized output waveform has more steps which produce staircase wave that approaches desired waveform. The problem of switching losses and power losses can be eliminated with minimum number of switches

SECTION I

INTRODUCTION

Sunlight is a widely available cheap source of energy, which can be converted to electricity through photovoltaic cells [1]. Solar panels produce direct current (DC) electricity whereas existing electricity infrastructure and electric appliances operate on alternating current (AC) electricity. DC/AC power converters, termed as inverters, are used for this conversion making electricity coming from solar panels useable [2]. Conventionally, two level inverters have been used for grid integration of solar system. However, these inverters give Pulsating waveforms of current and voltage at their outputs and filters are needed to get fundamental frequency sinusoidal waveforms. Efficiency of this process is low since energy contained in the higher order harmonics is wasted. Keeping in view higher costs and lower efficiencies of solar systems, it is important to devise new inversion methodologies to make compact, cheap and efficient solar systems. Many multilevel inverters topologies have been proposed in technical literature [3]–[8]. Neutral point clamped or diode clamped [9], the flying capacitor or capacitor clamped [10] and the cascaded H-bridge [11] topologies are considered as the three basic multilevel topologies. The neutral point clamped inverters were initially proposed for motor drive applications. They greatly reduce odd harmonic amplitudes compared with fundamental. DC link capacitor voltage unbalancing and requirement of large number of clamping diodes for higher number of voltage levels are the major disadvantages of this topology. The capacitor clamped topologies find applications in transformer-less systems [12], but these topologies require a large number of electrolytic capacitors which decreases their reliability. Cascaded H-bridge topologies are more suitable for getting higher number of voltage levels. They also have modular designs and simple control techniques. But they require separate DC sources. Multilevel inverters were first introduced for high power and high voltage applications [13], but in recent years, they have found applications in low power systems especially photovoltaic systems [6], [14]. Multilevel inverters exhibit superior characteristics as compared to traditional two level inverters. Due to higher number of voltage levels, output waveforms of multilevel inverters contains fewer harmonics essentially reducing the filter size or for some applications filter can be eliminated completely. Also, multilevel inverters operate at lower switching frequencies which decrease the switching losses and hence increase their efficiency. Moreover, multilevel inverters provide multiple DC links which may help in modular designs. Separate DC link voltage control makes them suitable for solar applications and separate tracking of maximum power points of solar panels is possible [6].

Multilevel inverters require a large number of power semiconductor switches to generate the output voltage with higher number of levels. Power switches require gate drivers and protection circuits, which makes overall circuit expensive. To overcome this issue, a number of hybrid multilevel inverters have been reported with the focus on getting maximum number of voltage levels with minimum number of power semiconductor switches and supporting circuit elements [15]–[20]. A very comprehensive summary of the characteristics of commonly used multilevel inverter topologies has been presented in [14]. It also proposes a new multiple transformer based topology for standalone photovoltaic applications. However, transformer based implementation can be costly. Gupta et. al., [15] compared classical and reduced device count topologies of multilevel converters and concluded that in process of reducing device count many compromises have to be made, which include higher voltage rating of power switches and loss of modularity etc. Authors in [17] and [18] proposed new multilevel inverter topologies with reduced number of device count. The proposed topologies are hybrid combination of modular sub multilevel converter and a full bridge converter. The main drawback of these topologies is that they use bidirectional power switches. Bidirectional power switches require complex drive circuitry and their implementation is not cost effective. Most of the existing multilevel topologies claim to reduce total number of device count. This objective can be misleading since the devices used in a multi-level inverter vary significantly in terms of their costs and complexities. Diodes and capacitors are cheap, and offer an easy placement in printed circuit boards. On the other hand, power switches are expensive, and a careful implementation of transistor gate drivers is required for their operation. Additional elements snubbing network, and resonant circuits [2] may also be required in some applications of these power switches. Based on that, an optimization for the reduced number of total device count as carried out may be misleading and less useful when one goes for a practical implementation. Instead, it appears more prudent to target a reduced number of switches only, when we seek an optimum implementation of multi-level inverter.

SECTION II

MULTILEVEL CASCADED INVERTERS

The cascade H-Bridge inverter is a H-Bridges connected in a series or cascade of H-Bridges [7]-[8]. The number of DC sources required to produce a (2n+1) output voltage levels in a multilevel cascade inverter is given by the relation.

$$M = 2n + 1 \quad \text{----}\rightarrow (1)$$

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.

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

Fig.1 illustrates the general structure of single phase cascaded multilevel H-bridge inverter. Each single phase H- bridge or full bridge contains separate DC source. A five level Cascaded multilevel inverter generates five output voltage levels such as Vdc, 2Vdc, 0, - Vdc, - 2Vdc with two DC separate voltage sources and a seven level cascaded multilevel inverter produces seven output voltage levels as Vdc, 2Vdc, 3Vdc, 0, - Vdc, - 2Vdc, - 3Vdc with three separate DC voltage sources. From Fig.1 it shows that each single phase full bridge contains four switches, S11, S12, S13, S14 are generates three output voltage levels such as Vdc, 0, - Vdc. + Vdc. The cascade multilevel inverters are scalable, good circuit layout due to series structure and switching redundancy feasible. Due to availability of separate DC voltage sources these inverters are restricted to certain applications.

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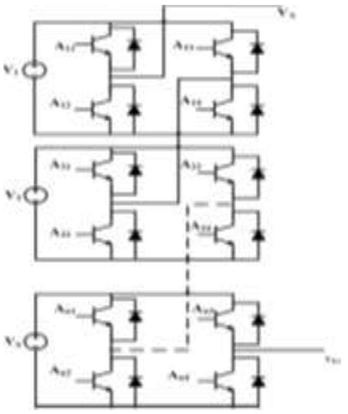

Fig 1: General structure of cascaded multilevel inverter

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]	1	1	[illegible]	[illegible]	1	1	[illegible]	[illegible]	1	1	-7Vdc

Fig (2): Sample Switching Table of 15 MULTILEVEL INVERTER

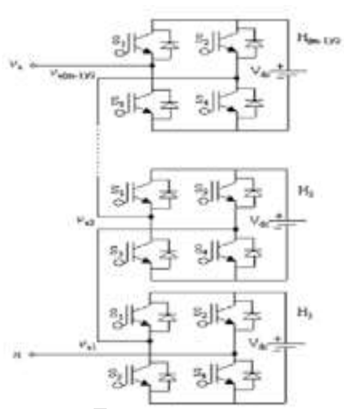

Fig (3): Cascaded H Bridge 15 level Mutilevel Inverter

The proposed topology is based on the modified H-bridge topology [9]. From conventional cascaded multilevel inverters it is observed that the proposed topology reduces the number of DC voltage sources and also switches. In this work we proposed new topologies for 9-level, 11-level, 13-level and 15-level inverters. All these inverters are derived from a 7-level inverter is presented. Figure.2 shows the 7-level inverter with modified H-bridges. This structure consists of six power switches and two unequal magnitudes of DC voltage sources. Since if the values of DC voltage sources are same, reduces the number of output voltage levels and hence to generate more number of voltage levels the magnitudes of voltage sources should be different values. In the proposed topology, k power switches are required to generate k levels staircase waveform Vbus. Four additional switches of H-bridge inverter are used to get staircase ac waveform Vac of 2k + 1 levels. Effectively, to generate 2k + 1 level staircase voltage ac waveform, only k + 4 power switches, k capacitors and k diodes are needed which results in overall lesser device count than an existing multilevel topology, to the best of our knowledge

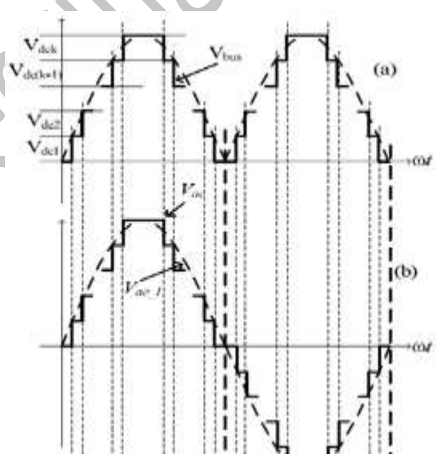

Fig (4): Output waveform and states of various switches

It should be pointed that the four switches used in the H bridge of our topology, require a large voltage rating. This is unlike the switches used in conventional diode-clamped and cascaded H-bridge topologies, where all the switches are of the same low voltage ratings. Although cost of a switch increases with its voltage rating, the required driver circuits usually remain the same. Based on that, a significant advantage in terms of cost and easy implementation is still offered by our proposed structure

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Simulation Circuit & wave form:

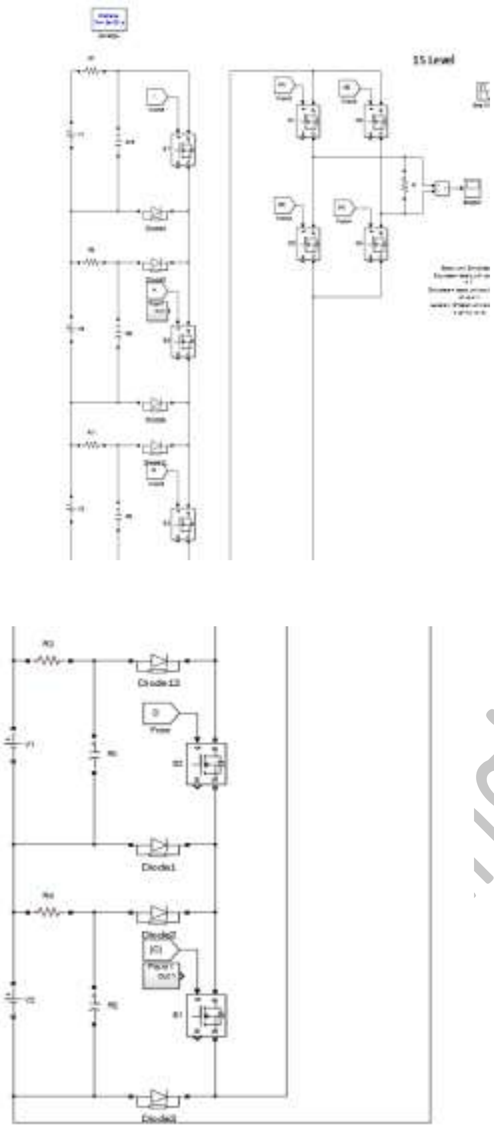

Fig (5): simulation Diagarm of Multilevel Inverter Topology

Controller Diagram:

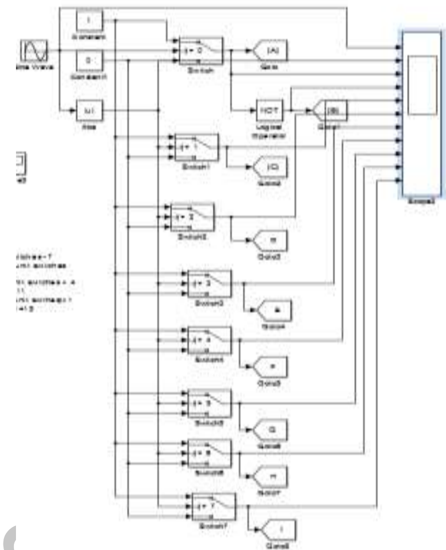

Fig (6):CONTROLLER of Cascaded H Bridge Multilevel

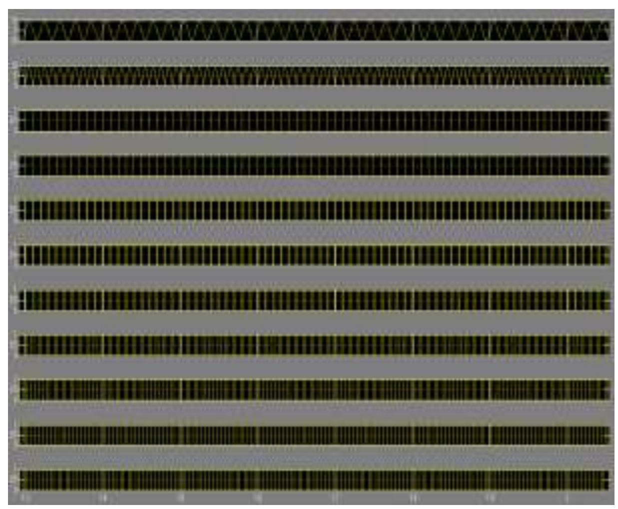

Fig (7) :Switching waveforms CHM

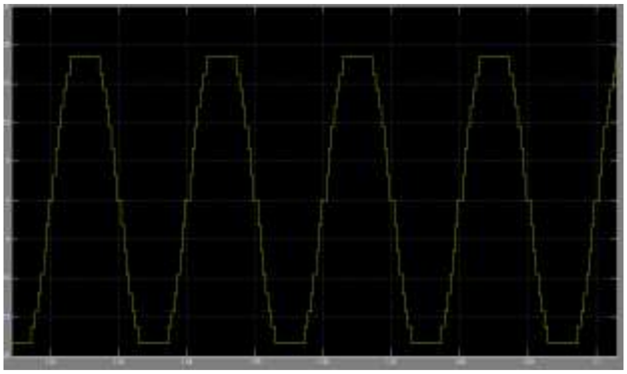

Fig (8): 15 level Multilevel Inverter waveform

SECTION III

HARDWARE MODEL

The hardware prototype model of the 15-level inverter is also built in the lab. The kit is shown in the figure 8.

Fig (8) Hardware model

Fig (9) Waveforms of 15-level output voltage

CONCLUSION

A new multilevel inverter topology has been proposed. The proposed topology is a hybrid combination of conventional diode clamped and H-bridge converters. It can be a good choice for photovoltaic applications where multiple separate DC sources are available. This paper has demonstrated the concept and working principles of the proposed topology. A detailed analysis of efficiency and practical implementation is still required to fully verify the advantages of this new circuit.

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Journal of Engineering Sciences

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