A NOVEL SINGLE-PHASE AND THREE PHASE MULTILEVEL INVERTER WITH REDUCED NUMBER OF SWITCHES FOR PHOTOVOLTAIC APPLICATION

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Abstract

Multilevel voltage source converters are emerging as a new breed of power converter options for high-power applications. The multilevel voltage source converters typically synthesize the staircase voltage wave from several levels of dc capacitor voltages. One of the major limitations of the multilevel converters is the voltage unbalance between different levels. The techniques to balance the voltage between different levels normally involve voltage clamping or capacitor charge control. There are several ways of implementing voltage balance in multilevel converters. Without considering the traditional magnetic coupled converters ,Several topologies for multilevel inverters have been proposed over the years; the most popular cascaded H- bridge apart from other multilevel inverters is the capability of utilizing different dc voltages on the individual H-bridge cells which results in splitting the power conversion amongst higher-voltage lower-frequency and lower-voltage higher- frequency inverters. Considering the cascaded inverter to be one unit, it can be seen that a higher number of voltage levels are available for a given number of semiconductor devices. The simplified multilevel inverter requires only six active switches instead of the eight required in the conventional cascaded H-bridge multilevel inverter. In addition, two active switches are operated at the line frequency. The studied multistring inverter topology offers strong advantages such as improved output waveforms, smaller filter size, and lower electromagnetic interference and total harmonics distortion. Finally an asymmetrical configuration is proposed with this we are getting seven levels with six switches.

I. INTRODUCTION

Recently the —multilevel converter‖ has drawn tremendous interest in the power industry [I]-[2]. The general structure of the multilevel converter is to synthesize a sinusoidal voltage from several levels of voltages, typically obtained from capacitor voltage sources. The so-called —multilevel‖ starts from three levels. A three-level converter, also known as a —neutral clamped‖ converter, consists of two capacitor voltages in series and uses the center tap as the neutral [3]. Each phase leg of the three-level converter has two pairs of switching devices in series. The center of each device pair is clamped to the neutral through clamping diodes. The waveform obtained from a three-level converter is a quasi-square wave output.

Renewable energy resources (RES) have had increasing penetration levels for grid connected distributed generation

(DG)in recent years. Photovoltaic, micro-turbine, wind turbine and fuel cell put forward many promising applications with high efficiency and low emissions. Together with power electronics technologies, these have provided an important improvement for RES and DG applications; especially, a micro grid concept is introduced in to provide more system capacity and control flexibility when several RESs with different electric behaviors are integrated in the same grid. The micro grid also offers extra degrees of freedom to optimize RESs connected to the utility grid; additionally, power quality requirements, system reliability and control flexibility would be achieved by using the micro grid concept as discussed in [4].

In photovoltaic systems, solar energy is converted into electrical energy by photovoltaic (PV) arrays. PV arrays are very popular since they are clean, inexhaustible and require little maintenance. Photovoltaic systems require interfacing power converters between the PV arrays and the grid. These power converters are used for two major tasks. First ,to ensure that the PV arrays are operated at the maximum power point (MPPT) [5-7]. Second, inject a sinusoidal current into the grid. Normally there are two power converters [8,9]. The first one is a DC/DC power converter that is used to operate the PV arrays at the maximum power point. The other one is a DC/AC power converter to interconnect the photovoltaic system to the grid.The classical single or three-phase two level voltage source inverter is normally used for this power converter type [10-12]. However, other topologies have been proposed. Multilevel converter topologies are a very interesting choice for realizing this objective.

Additionally, due to its modular structure, the hardware implementation is rather simple and the maintenance operation is easier than alternative multilevel converters. The multilevel voltage source inverter is recently applied in many industrial applications such as ac power supplies, static VAR compensators, drive systems, etc. One of the significant advantages of multilevel configuration is the harmonic reduction in the output waveform without increasing switching frequency or decreasing the inverter power output [5-11]. The output voltage waveform of a multilevel inverter is composed of the number of levels of voltages, typically obtained from capacitor voltage sourcesThe so-called multilevel starts from three levels. As the number of levels reach infinity, the output THD approaches zero. The number of the achievable voltage

levels, however, is limited by voltage unbalance problems voltage clamping requirement, circuit layout, and packaging constraints.

A single-phase multistring five-level inverter integrated with an auxiliary circuit was recently proposed for dc/ac power conversion [12], [13]. This topology used in the power stage offers an important improvement in terms of lower component count and reduced output harmonics. Unfortunately, high switching losses in the additional auxiliary circuit caused the efficiency of the multistring five- level inverter to be approximately 4% less than that of the conventional multistring three-level inverter [13]. In [14], a novel isolated single-phase inverter with generalized zero vectors (GZV) modulation scheme was first presented to simplify the configuration. However, this circuit can still only operate in a limited voltage range for practical applications and suffer degradation in the overall efficiency as the duty cycle of the dc-side switch of the front-end conventional boost converter approaches unity [6], [14]. Furthermore, the use of isolated transformer with multi windings of the GZV based inverter results in the larger size, weight, and additional expense [14]. The newly constructed inverter topology offer strong advantages such as improved output waveforms, smaller filter size, and lower EMI and total harmonics distortion (THD). In this letter, the operating principle of the developed system is described, and a prototype is constructed for verifying the effectiveness of the topology.

II. SYSTEM CONFIGURATION OF OPERATION PRINCIPLES

A general overview of different types of PV modules or fuel cell inverters is given in [9] and [17]. This letter presents a multi string multilevel inverter for DERs application. The multi string inverter shown in Fig. 1 is a further development of the string inverter, whereby several strings are interfaced with their own dc/dc converter to a common inverter [18]. This centralized system is beneficial because each string can be controlled individually. Thus, the operator may start his own PV/fuel cell power plant with a few modules. Further enlargements are easily achieved because a new string with a dc/dc converter can be plugged into the existing platform, enabling a flexible design with high efficiency [9]. The single- phase multi string multilevel inverter topology used in this study is shown in Fig. 2.

This topology configuration consists of two high step-up dc/dc converters connected to their individual dc-bus capacitor and a simplified multilevel inverter. Input sources, DER module 1, and DER module 2 are connected to the inverter followed a linear resistive load through the high step-up dc/dc converters. The studied simplified five-level inverter is used instead of a conventional cascaded pulse width-modulated (PWM) inverter because it offers strong advantages such as improved output waveforms, smaller filter size, and lower EMI and THD [19]– [25]. It should be noted that, by using the independent voltage

Regulation control of the individual high step-up converter, voltage balance control for the two bus capacitors Cbus1, Cbus2 can be achieved naturally.

A Full H-Bridge Inverter

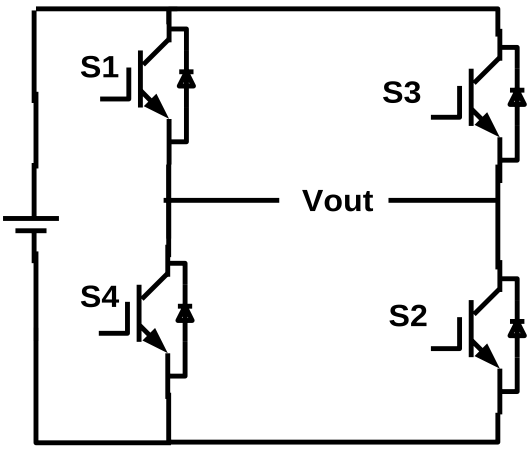


Figure. 1 Full H-Bridge

Fig.1 shows the Full H-Bridge Configuration. By using single H-Bridge we can get 3 voltage levels. The number output voltage levels of cascaded Full H-Bridge are given by 2n+1 and voltage step of each level is given by Vdc/n. Where n is number of H-bridges connected in case caded. The switching table is given in Table 1.

Table1. Switching table for Full H-Bridge

SwitchesTurnON	VoltageLevel
S1,S2	Vdc
S3,S4	-Vdc
S4,D2	0

Simplified Multilevel Inverter Stage

A new single-phase multi string topology, presented as a new basic circuitry in Fig. 3. Referring to Fig. 2, it should be assumed that, in this configuration, the two capacitors in the capacitive voltage divider are connected directly across the dc bus, and all switching combinations are activated in an output cycle. The dynamic voltage balance between the two capacitors is automatically controlled by the preceding high step-up converter stage. Then, we can Assume Vs1 = Vs2 = Vs

This topology includes six power switches—two fewer than the CCHB inverter with eight power switches—which drastically reduces the power circuit complexity and simplifies modulator circuit design and implementation. The phase disposition (PD) PWM control scheme is introduced to generate switching signals and to produce five output-voltage levels: 0, VS, 2VS ,−VS , and −2VS . This inverter topology uses two carrier signals and one reference to generate PWM signals for the switches. The modulation strategy and its implemented logic scheme in Fig. 4(a) and (b) are a widely used alternative for PD modulation. With the exception of an offset value equivalent to the carrier signal amplitude, two comparators are used in this scheme with identical carrier signals Vtri1 and Vtri2 to provide high-frequency switching signals for switches Sa1, Sb1, Sa3, and Sb3. Another comparator is used for zero-crossing detection to provide line- frequency switching signals for switches Sa2 and Sb2.

The required five output levels and the corresponding operation modes of the multi-level inverter stage are described clearly as follows.

1) Maximum positive output, 2VS: Active switches Sa 2, Sb1 , and Sb 3 are ON; the voltage applied to the LC output filter is 2VS .

2) Half-level positive output, +Vs: This output condition can be induced by two different switching combinations. One switching combination is such that active switches Sa 2 ,Sb 1

, and Sa 3 are ON; the other is such that active switches Sa 2 , Sa 1 , and Sb 3 are ON. During this operating stage, the voltage applied to the LC output filter is +Vs.

3) Zero output, 0: This output condition can be formed by either of the two switching structures. Once the left or right switching leg is ON, the load will be short-circuited, and the voltage applied to the load terminals.

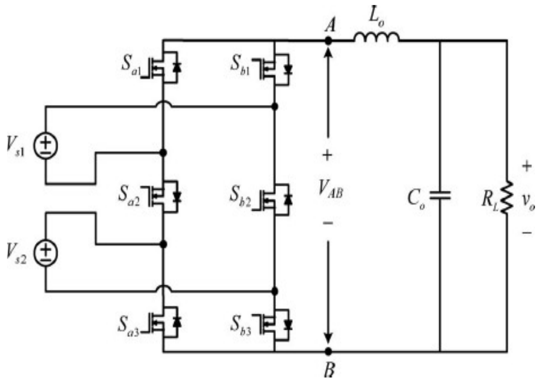
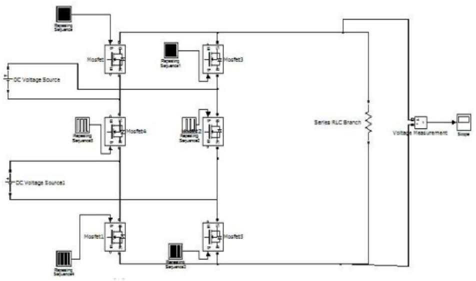


Figure.2 Basic five-level inverter circuitry



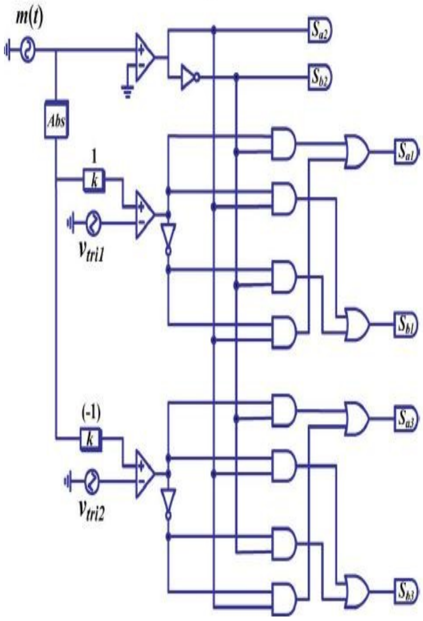


Figure.3 modulation logic

4) Half-level negative output, −Vs: This output condition can be induced by either of the two different switching combinations. One switching combination is such that active switches Sa 1, Sb 2, and Sb 3 are ON; the other is such that active switches Sa 3, Sb 1, and Sb 2 are ON.

5)Maximum negative output, −2Vs: During this stage, active switches Sa 1, Sa 3, and Sb 2 are ON, and the voltage applied to the LC output filter is −2Vs.

III. MATLAB/SIMULINK MODEL & SIMULATION RESULTS

Figure.3 Simulation circuit

The basic simulation circuit, Figure.3 is a multi-string inverter with combination six switches. Based on the selection of switches in the circuit output voltage are obtained.

Figure.4 The simulation circuit of 7level inverter

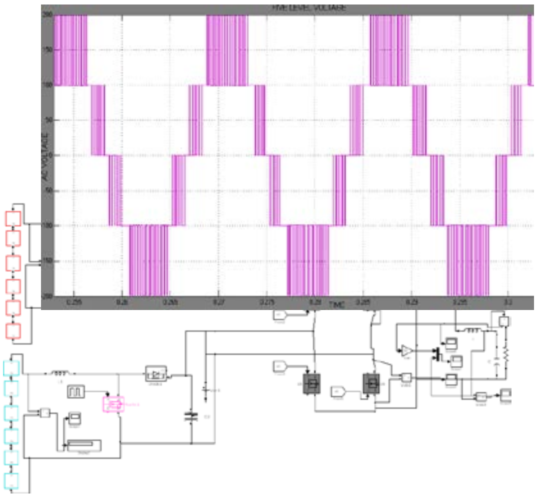
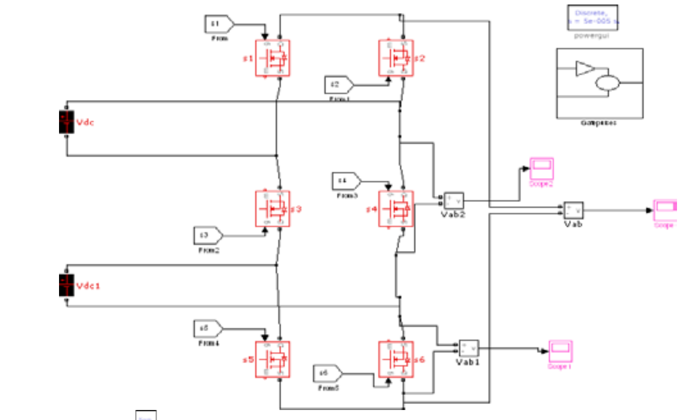


Figure.4 shows the 7 level multi string inverter which is having the same 5 level circuit but obtaining the 7 level output voltages

Figure:5Simulation circuit of multi string inverter with photo voltaic

Figure.5 is a multi-string inverter with a photo voltaic array, such that a group of photo voltaic cells together forms as an energy source.



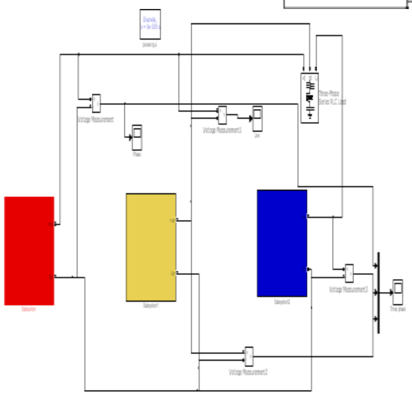


Figure.6 Simulation circuit of three phase multi string inverter

Figure.6 is a three phase multi string inverter, which is a combination three single phase multi string inverters.

Figure.7 Output voltage waveform of 5 level multi sting inverter using PWM

Figure.7 shows the output voltages which are obtained by the multi string inverter of 5 level using PWM

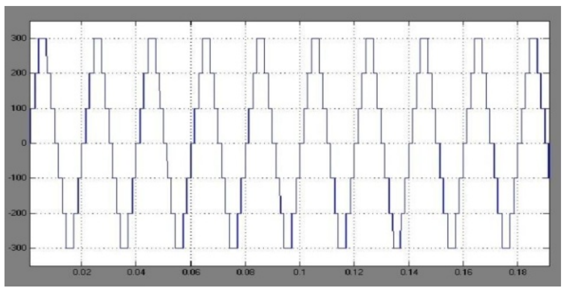


Figure.8 Output voltage waveform of 7level multi string inverter

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Figure.8 shows the 7 level output voltage waveform of multi string inverter.

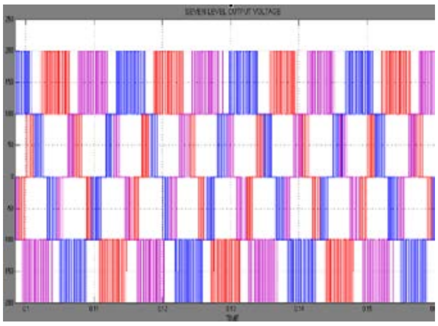

Figure. 9 Three phase output voltage of three phase multi string inverter

Figure.9 shows the three phase output voltage waveform of the multi string inverter

CONCLUSION

This paper presents a new Novel Asymmetrical Multistring multilevel converter. Here we proposed single phase and three phase multistring multilevel inverters, the proposed converter produces more voltage levels with less number of switches compared to H- bridge configuration. This will reduce the switching losses and number of gate drivers and protection circuits which in turn reduces the cost and complexity of the circuit. Finally a three phase model of the proposed circuit is shown and simulation results are presented.

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