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A Modular Single-Phase Multistring Multilevel Inverter Topology for Distributed Energy Resources

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Abstract

This Paper presents simulation analysis of single phase multilevel inverter for distributed energy resources(DER) system are small power generation tools, in order to reduce conversion losses, complexity of the circuit and to improve the size and cost of the system. The system involves a high step up converter is used to set up the voltage coming from the various DER's such as Fuel cell module and Photovoltaic module, this high voltage acts as input to the inverter. This system requires less number of switches as compare to conventional cascade H-bridge (CCHB) inverter. There are some advantages of this multilevel inverter such as improved output waveform, and lower Electromagnetic interference, lower switching power loss and Total Harmonic Distortion (THD).

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Keywords: DC/DC Converter; Multilevel inverter.

1. Introduction

In recent years due to public concern about global warming and climate change, therefore we have to look on environmentally friendly distributed energy recourses systems (DER's). For supplying premium electric power in terms of high efficiency, reliability, and power quality, integrating interface converters of DER's such as photovoltaic (PV), wind power micro turbines, and fuel cells into the micro grid system [1]-[4]. In such a system most DER's supply a DC voltage that varies in a wide range according to various load condition. Thus a dc/ac power processing interface is required and is compliable with residential, industrial and utility grid standards [4]. For low –medium power application, to reduce the cost, size and weight of the converter we can use high frequency transformers or make no use of transformer, as the output voltage level increase.

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The output harmonics of such inverter decreases which allows the less expensive output filter. As a result multilevel inverter topology is developed which has reduced number of power switches which allowing the reduction of electromagnetic interference (EMI) and switching losses [5]. The objective of this paper to study and simulation results of A Modular Single-phase Multistring Multilevel inverter Topology for Distributed Energy Resources to overcome the above problem. A Modular five level Inverter requires only six active switches instead of the eight required in the Conventional cascaded H-bridge (CCHB) inverter [2]. Improved output waveforms, lower total harmonic distortion (THD), smaller filter size these are some advantages of the A Modular Inverter topology.

2. System Configuration

A general overview of the various types PV modules or fuel cell inverter is given in [3] and [6]. This paper presents a multistring multilevel inverter for DERs application. In Fig. 1 shown further development of the string inverter, where by several strings are interfaced with their own dc/dc converter

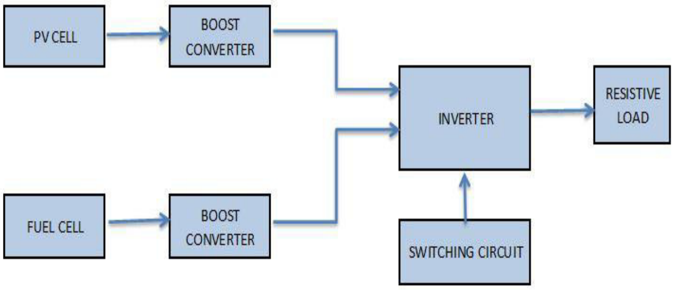

Fig.1 Block Diagram of proposed system for A Modular multistring multilevel inverter topology.

In this centralized system beneficial because each string can be controlled individually. Thus, the operator can start his own PV/fuel cell power plant with a few modules further expansion are easily achieved because a new string with a dc/dc converter because of the more advantages of A Modular inverter over the conventional cascaded H-bridge inverter we use A Modular inverter topology.

2.1 High step-up Converter Stage

A high step-up converter topology is used, which is composed of one IGBT, one inductor, one capacitor, and two diodes this converter using boosting the DC voltage of various DER's such as PV module and fuel- cell module.

Boost Converter Design equations as follows:

$$D = \frac{Vout - Vin}{Vin} \quad \text{.......... ....1}$$

$$\Delta_{IL} = \frac{IoutXVout}{Vin} X\,0.2 \quad \text{.......... .2}$$

$$L = \frac{VinXD}{\Delta_{IL} XFs} \quad \text{.......... .... 3}$$

$$C = \frac{IoutXD}{FsX\Delta_{V}} \quad \text{.......... .... 4}$$

2.2 A Modular Multilevel Inverter stage

The Increasing demand for industrial power converters and some advantages of multilevel inverter such as low distortion in output voltage, low harmonic and electromagnetic interference. Up to now several multilevel inverter are present. A Modular multilevel converter consists of six power switches, two fewer than the CCHB inverter with eight power switches used. So, it drastically reduces 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,* 2*Vs,-Vs and -*2*Vs.* The inverter topology uses two carrier signals and one reference to generate PWM signals for the switches. The modulation strategy and its and its implemented logic scheme in Fig. 2(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 V_{tri1} and V_{tri2} to provide high-frequency switching signals for switches S_{a1}, S_{b1}, S_{a3}, and S_{b3}. Another comparator is used for zero-crossing detection to provide line frequency switching signals for switches S_{a2} and S_{b2}.

Table 1: Switching Combinations

Sa1	Sa2	Sa3	Sb1	Sb2	Sb3	VAB
0	1	0	1	0	1	2Vs
0	1	1	1	0	0	Vs
1	1	0	0	0	1	Vs
1	1	1	0	0	0	0
0	0	0	1	1	1	0
1	0	0	0	1	1	-Vs
0	0	1	1	1	0	-Vs
1	0	1	0	1	0	-2Vs

The switching function of switches in is defined as follows:-

$$S_{aj} = 1 \text{ , } S_{aj} \text{ ON}$$
$$= 0 \text{ , } S_{aj} \text{ OFF} \quad \text{for j= 1,2,3}$$

$$S_{bj} = 1 \text{ , } S_{bj} \text{ ON}$$
$$= 0 \text{ , } S_{bj} \text{ OFF} \quad \text{for j= 1,2,3}$$

Table 1 lists switching combinations that generate the required five output voltage levels. The corresponding operation modes of the multilevel inverter stage are described clearly as follows.

1) Maximum positive output, 2Vs: Active switches *Sa2, Sb1* and *Sb3* 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 *Sa2, Sb1, and* Sa3 are ON; the other is such that active switches *Sa2, Sa1* and *Sb3* 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 combinations. Once the left or right switching leg is ON, the load will be short circuited, and the voltage applied to the load terminals is zero.
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 *Sa1*, *Sb2*, and *Sb3* are ON; the other is such that active switches *Sa3*, Sb1, and *Sb2* are ON.

5) Maximum negative output, -2Vs during this stage switches *Sa1*, *Sa3* and *Sb2* are ON, and the voltage applied to the LC output filter is -2Vs.

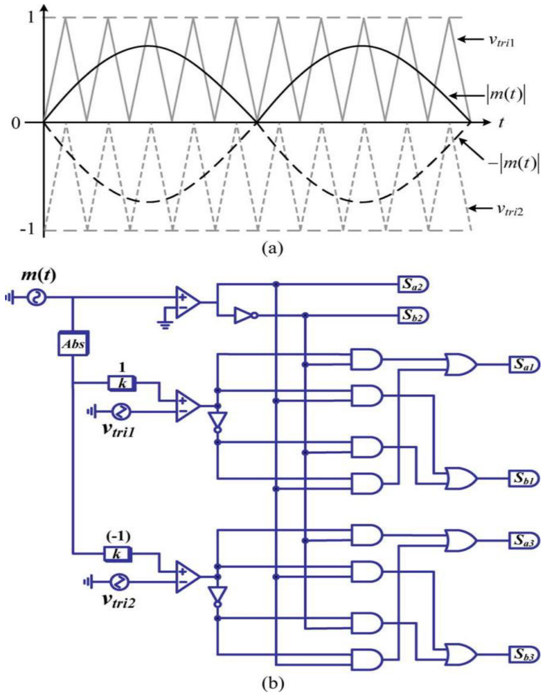

Fig .2 Modulation strategy (a) carrier/reference signals (b) Modulation logic

3. Simulation Results

Table 2 shows the Modular inverter THD Value and CCHB (Conventional Cascaded H-bridge) inverter THD. It is seen that THD is less in Modular type than conventional type inverter.

Table 2 FFT Analysis of VAB (five level voltage)

Type of inverter	THD Value in %
Modular five level inverter	21.65 %
CCHB five level inverter	39.04 %

The specifications of the two preceding high step-up dc/dc converters are

1) Input voltage 24V dc from PV cell and Fuel cell.

2) Controlled Output voltage 100V dc.

3) The corresponding specifications of the Modular multilevel inverter dc/ac inverter stage are 1) output power, Po=230W; 2) input voltage, Vs=100V dc; 3) output voltage, Vo= 110Vrms ac.

4) Line frequency 50Hz. And the output connected to 100 Ω Resistive Load.

The average switching power loss Ps caused by these transitions can define as

Ps = 0.5VDSIofs [tc(on) + tc(off)]

Where tc(on) and tc(off) are the turn-on and turn-off crossover intervals, respectively; VDS is the voltage across the switch; and Io is the entire current which flows through the switch. For simplification both the proposed system circuit and CCHB inverter are operated same turn-on and turn-off crossover intervals and at the same load Io. Then the average switching power loss Ps is proportional to VDs and fs as *Ps α VDs*. Fig. 3 and Fig. 4 show the FFT analysis of Modular five level inverter and CCHB five level inverter respectively.

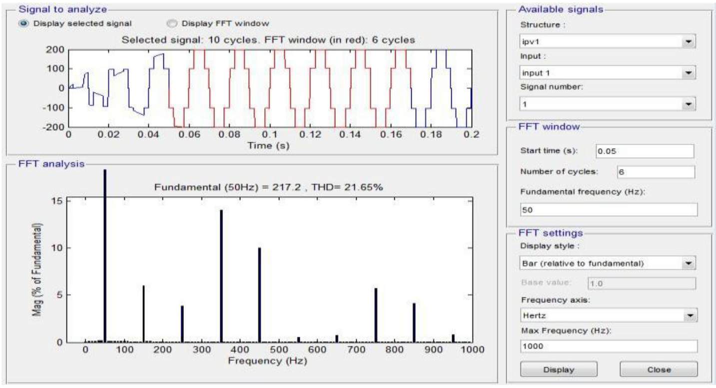

Fig.3 FFT Analysis *VAB* of Modular five level inverter.

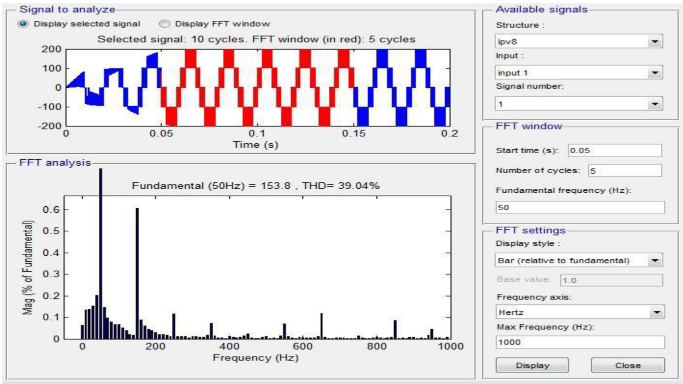

Fig.4 FFT Analysis *VAB* of CCHB five level inverter

4. Conclusion

This Paper presents A Modular single phase multistring multilevel inverter topology that reduces significant reduction in the number of power devices required to implement multilevel output Voltage. Eight number of switches used in CCHB inverter, where as in A Modular inverter six numbers of switches are used, and two numbers of switches less than the CCHB inverter. The switching power loss Ps compared with the CCHB circuit topology, the voltage stresses of eight switches of the CCHB inverter are all equal to Vs (Source voltage). Ps is proportional to VDs (Voltage across the switch) and fs. Ps α VDsfs For CCHB inverter from eight switches Ps α 8VDsfs Similarly the switching losses of Modular single phase five level inverter Sa2 and Sb2 activated twice in a line frequency (fs > fm) the average switching losses approximately Ps α 4VDsfs. The switching power loss nearly half that of the CCHB inverter.The Modular inverter topology offer advantages such as improved output waveforms, Lower EMI, THD, and less number of switches, less switching power loss Ps compared to CCHB inverter. It reduces the number of gate drivers which will in turn reduce the cost and complexity of the circuit. Simulation results show the effectiveness of the proposed system.

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