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Transformer-less Inverters for Single Phase Grid Connected PV System with MATLAB Simulation

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Abstract

Abstract: Transformer-less inverter are more attractive for grid-tied photovoltaic (PV) system as it has got many advantages such as higher efficiency, lower cost, smaller size, weight, etc., however unfortunately, a leakage current flows through the system. In order to reduce the leakage current and the safety requirement of the leakage current, various transformers-less inverter topologies have been proposed. In this paper HERIC, H5 and 5 level multi-level inverters have been evaluated for their performances in terms of efficiency. The intrinsic relationship of harmonics between these inverters has been discussed in this paper. Also, the relationship between these inverters and the cost effectiveness has been analysed in this paper. 5 level multi-level inverter has been taken for the detailed analysis with operation modes and modulation strategy with MATLAB simulation.

***Keywords:* Transformer-less inverters, Harmonics, 5 level multi-level inverter, efficiency, MATLAB simulation.**

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1. INTRODUCTION

An inverter is an electrical circuit capable of converting DC power into AC power, while at the same time regulating the voltage, current and frequency of the signal. As we know that inverters are finding their extensive uses now a days. Previously they were only used in some main applications, which would be large scale and expensive. But now a day, inverters are like a small compulsory electronic device, on which many of our other main electronic equipment depend. Inverters come in all different shapes and sizes, for all different purposes. Inverters vary in output from 50-5000W. There are several different methods of converting DC power to AC power, some inverters put out electricity of higher quality than others. They are extensively used, not only because of their universal function of converting DC power to AC power, but also because of their high efficiency, reduced power costs and versatile applications[2].

Fig -1: Block Diagram of DC to AC converter [4]

An inverter is connected to DC source and it converts it into AC power in its circuit [6].

The details of input and output are as under.

- The input is DC power. The value of input voltage depends upon the application. Some applications require 12V while some may require very high voltages of thousands of volts.
- The ideal output of an inverter is a sinusoidal waveform. Such a wave gives continuous flow of power. But the output from the circuit is generally not ideal. It gives output in the form of square wave, quasi-square wave or PWM.

2. TYPES OF INVERTERS

2.1 HERIC Inverter:

Highly efficient and Reliable Inverter Concept (HERIC) topology is based on a full bridge circuit which is group of power switches operated at a high switching frequency during one half wave of the output voltage. The circuit has an additional branch of switches, each one active during half wave period of the grid wave form. This bridge provides a path for the freewheeling current, eliminating the circulation of reactive power and increasing the efficiency and voltage [1].

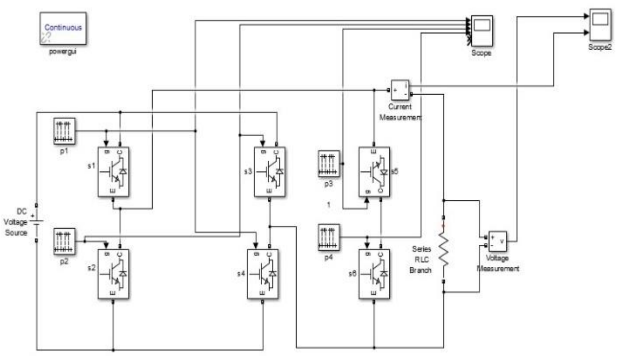

Fig-2: Simulation of Heric Topology with Resistive load

The main drawback in this topology is increased number of semiconductors. There are four operation modes in each period of utility grid of the HERIC topology.

As shown in the figure 1.1, apart from the normal full bridge switches and diodes the topology has two extra IGBT switches (S5 and S6) and two diodes (D5 and D6). The main function of two extra switches is to provide a freewheeling path for the output current. The bridge with IGBT S6/D6 provides a path during the positive half wave of the grid cycle and provides a path during this period. This operation short circuits the output of the inverter in the period when the switches S1 and S4 or S2 and S3 are off and thus separates the PV from the grid [3].

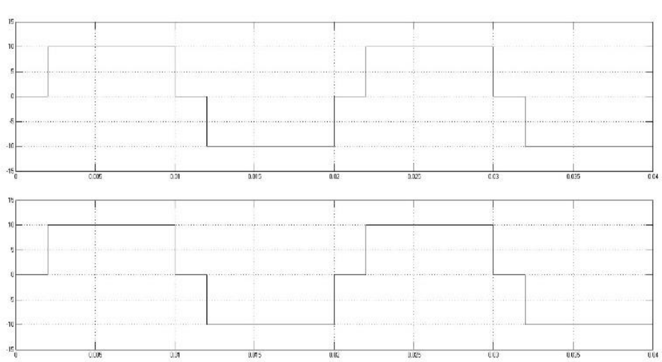

Fig-3: Output Results of Heric Topology

2.2 H5 Inverter:

This circuit is based on the full bridge with the same operations of the bridge switches. It has an extra power switch and anti-paralleled diode on the DC side of the inverter to electrically decouple the AC from the DC side during freewheeling period. Its main drawback is the higher conduction losses due to series associated of three switches during the active phase [1].

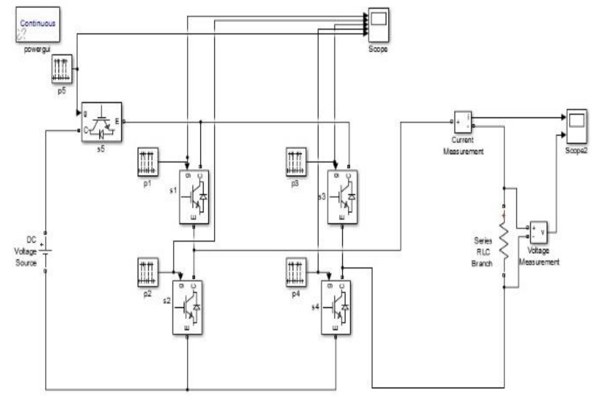

Fig-4: Simulation of H5 Topology with Resistive load

As shown in the figure 2.1, apart from the normal full bridge switch and diode the topology has one extra IGBT switch (S5) and one diodes (D5). The main function of one extra switch is to control input path. This operation of circuits the output of the inverter in the period when the switches S1 and S4 or S2 and S3 are off and thus separates the PV from the grid.

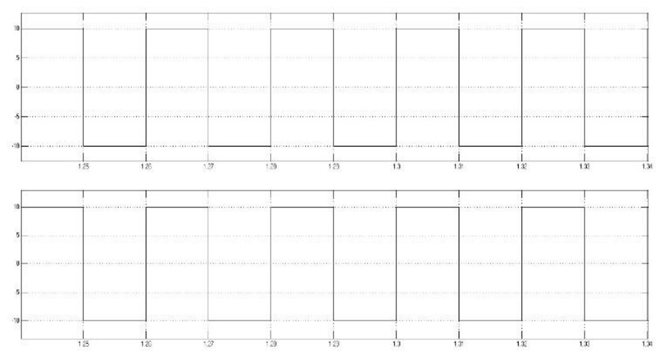

Fig-5: Output Results of H5 Topology

2.3 5 Level Multi-level Inverter:

As the name suggests this topology consists of H-bridges connected in a cascade connection with each other. As the number of voltage level of the MLI goes on increasing according to it the number of H-bridges also increases. For a general n-level cascaded H-bridge MLI we need (2n+1) H-bridges [4].

2.3.1 Simulation of 5-Level Cascaded MLI with Resistive load.

The simulation of cascaded H-bridge MLI of equal voltage sources with resistive load was performed using the MATLAB software the circuit connection and the output of simulation circuit are shown in Fig-6 and Fig-7 respectively.

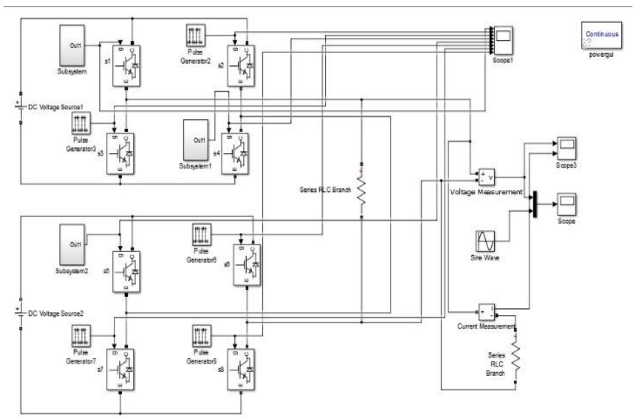

Fig-6: Simulation of 5-Level Cascaded MLI with Resistive load.

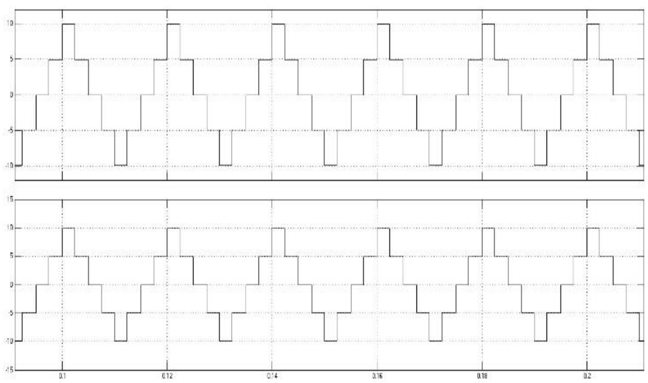

Fig-7: Output Results of 5-Level Cascaded MLI Topology with resistive load.

2.3.2 Simulation of MLI with Inductive load.

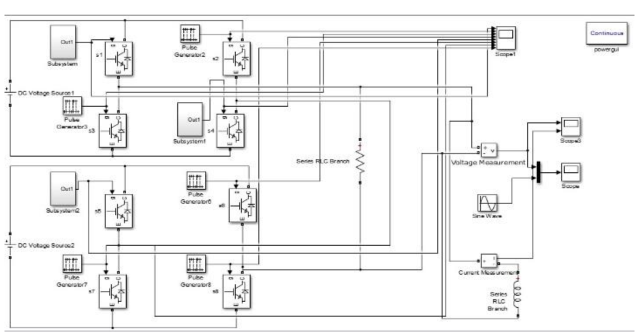

Fig-8: Simulation of 5-Level Cascaded MLI with Inductive load.

The simulation of cascaded H-bridge MLI of equal voltage sources with resistive load was performed using the MATLAB software the circuit connection and the output of simulation circuit are shown in Figure-3.3 and Figure-3.4 respectively [5].

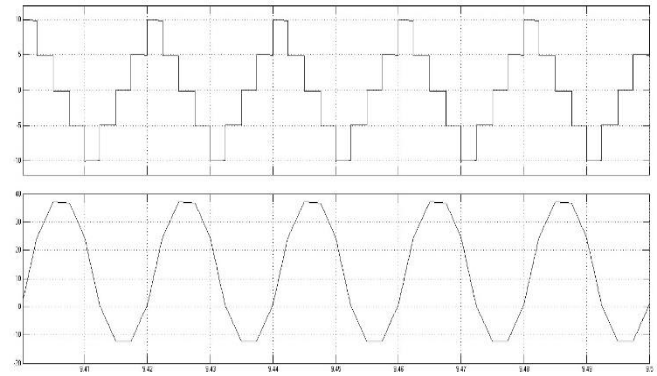

Fig-9: Output Results of 5-Level Cascaded MLI Topology with Inductive load

The gate pulses required for the 5-level cascaded MLI is shown in Table-1[5]:

Table-1: Comparison of H5, Heric and 5-Level Cascaded MLI

Output	S1	S2	S3	S4	S5	S6	S7	S8
2V	1	0	0	1	1	0	0	1
V	1	0	0	1	1	1	0	0
0	1	1	0	0	1	1	0	0
-V	1	1	0	0	0	1	1	0
-2V	0	1	1	0	0	1	1	0
-V	1	1	0	0	0	1	1	0
0	1	1	0	0	1	1	0	0
V	1	0	0	1	1	1	0	0

Parameters	H5 Inverter	Heric Inverter	Multilevel Inverter	
No. of levels	3	3	5	
No. of Switches Required	5	6	8	
No. of GATE pulses Required	3	4	8	
No. of Voltage Source Required	1	1	2	
No. of Extra Logic Gates Required	None	None	Required	
No. of H-Bridges Required	1	1	2	
No. of Controlled Devices Required	5	6	8	
No. of FW Switches Required	1	2	None	
Types Of Load	R	R	R	L
LOH in Voltage	5^{th}	5^{th}	7^{th}	3^{rd}
Voltage THD	48.35%	30.48%	29%	32%

3. CONCLUSION

In this paper, various topologies and control strategies of H5, Heric and 5-level cascaded MLI which can be used for PV-grid connected applications were studied. Simulation was done to verify the theoretical aspects. This paper might help the researchers to choose appropriate topology of Inverters for a specific application. Based on the comparison we can choose 5-level cascaded topology of inverter for PV-grid connected applications.

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