Research Article Impact Factor: 4.226 ISSN: 2319-507X
Sneha Khubalkar, IJPRET, 2016; Volume 4 (9): 113-120 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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DESIGNING OF BALANCE CONTROL CIRCUIT FOR SINGLE PHASE SEVEN-LEVEL CASCADED H-BRIDGE CONVERTER

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Accepted Date: 15/03/2016; Published Date: 01/05/2016

Abstract: This paper presents balance control circuit for single phase seven-level cascaded H-bridge converter. The aim of the proposed technique is to as minimize the voltage unbalance by using photovoltaic cell. By using photovoltaic cell efficiency of the system increases. CHB topology is easy to install and requires a minimum number of components compared to other multilevel inverter topologies. A voltage oriented control based on space vector pulse width modulation technique is used for the control of the converter. The problem of voltage imbalance will be overcome. The inverter topology consists of three H-bridge cells connected in series. The performance of single phase cascaded H-bridge converter has been evaluated using MATLAB. In this paper a single phase seven-level cascaded H-bridge inverter topology has been proposed for the power generation system of renewable energy sources. The power imbalance in the grid will be overcome by using photovoltaic energy conversion system i.e. renewable energy source. The proposed technique has been validated through the use of simulation and experimental testing and results.

Keywords: Cascaded H-bridge 7-level inverter, Developed H-bridge 7-level inverter, power switches.

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How to Cite This Article:

Sneha Khubalkar, IJPRET, 2016; Volume 4 (9): 113-120

PAPER-QR CODE

INTRODUCTION

The devices which convert DC power to AC power at required output voltage and frequency level is known as inverter. In medium and high power conversions, multilevel inverters are increasingly being used because of their attractive features such as enhanced output voltage profile, reduced voltage stress across semiconductor switches, low common-mode voltage. Various multilevel inverter topologies are reported in the literature and the most common ones are Diode Clamped Multilevel Inverter (DC-MLI), Flying Capacitor Multilevel Inverter (FC-MLI) and Cascaded H-Bridge Multilevel Inverter (CHB-MLI). Multilevel converter allows operating at voltage levels higher than the limits of the individual power switches in the conversion process. Moreover it can generate high quality currents and voltages with reduced common mode voltages and smaller voltage changes as well as the generation of lower EMI with reduced switching frequency and with higher efficiency [1].The quality of output voltage, current and therefore power of a converter depends on modulation technique used. The multi-level inverters are primarily classified as Flying capacitor inverter, Diode clamped and Cascaded H – Bridge multilevel inverter.

CHB multilevel inverter is popular in high power applications due to its modular structure and enhanced input power quality [2]. The size and bulkiness of passive filters can be reduced by using Cascaded H-bridge converter. These inverters generate a stepped voltage waveform by proper arrangement of semiconductor devices and number of dc voltage sources as an input. Cascaded H – Bridge (CHB) multilevel inverter needs a number of isolated dc supplies, each of which feeds an individual H-bridge power cell. The number of H-bridge cells in a CHB inverter is mainly decided by the inverter operating voltage, harmonic requirements, and manufacturing cost. Conventional cascaded H-bridge inverter requires number of power switches which need corresponding gate drive circuitry. This leads to increase in the complexity of the circuit and also increases the total cost of the inverter. The cascaded H-Bridge (CHB) multi-level converter topology has been widely proposed for PV conversion applications, because it offers a modular solution by collecting large numbers of PV panels as an isolated DC sources which allow generating a large number of voltage levels in the output. These combinations achieve an individual maximum power point tracking (MPPT) through DC-DC converters improving the conversion efficiency of the system. CHB topology has some other advantages such as flexible design, easy installation and it requires a minimum number of components when compared to other multilevel inverter topologies with the same number of levels. Thus a cascaded inverter is one of the best topologies for high voltage grid connected photovoltaic systems. However, this advantage comes along with drawbacks, which are the inherent power imbalance between cells in each leg as well as a power imbalance among the different phases of the inverter caused by dust accumulation, partial shading and module mismatch of the array. For solving these problems a simple feed forward mechanism was added to the control scheme as compensation to overcome the imbalance in DC-link capacitors voltages but unfortunately no laboratory results were presented for the validation of this solution. Power imbalance in the CHB were eliminated by connecting the whole PV generated power to a single dc-bus bar and a traditional Voltage Oriented Control was used for the grid tie CHB inverter to control the grid currents and dc-bus bar voltage without the need of any balancing algorithm. The control scheme is simple and was realized based on voltage oriented control (VOC) similar to the schemes reported.

LITERATURE REVIEW

Balance control for large scale photovoltaic systems is very necessary. This requires various converter topologies. The literature survey is based on following papers:
O. Taha and M. Pacas (2014) proposed a balance control for three-phase grid connection 5-level cascaded H-Bridge converter. A voltage oriented control based on space vector pulse width modulation technique is used in this paper for the control of the converter by using only single DSP. Feed-forward modulation index compensation is applied to overcome the problem of voltage imbalance among the different phases [1]. L. Tarsciotti (2014) proposed active DC voltage balancing PWM technique for high-power cascaded multilevel converters. In this paper a dedicated PWM technique specifically designed for single-phase multilevel CHB converters [2]. I. Sarkar (2014) proposed modified hybrid multi-carrier PWM technique for cascaded H-bridge multilevel inverter. The performance comparison modified carrier disposition PWM and hybrid-PWM technique is presented for a 7-level CHB multilevel inverter for same device switching frequency [3]. P. Kumar (2014) proposed a three-level common-mode voltage eliminated inverter with single dc supply using flying capacitor inverter and cascaded H-bridge. This paper gives the advantages that if one of devices in the H-bridge fails, the system can still be operated as a normal three-level inverter at full power [4]. A. Fernandez (2013) proposed a model-based controller for the cascade H-bridge multilevel converter used as a shunt active filter. In this paper a controller is proposed to compensate for harmonic distortion and reactive power caused by a nonlinear load [5]. T.Zhao (2013) proposed voltage and power balance control for a cascaded H-bridge converter-based solid state transformer. This paper is based on the single phase dq model. A novel voltage and the power control strategy is proposed to balance the rectifier capacitor voltages and real power [6]. H.Sepahvand(2013) proposed capacitor voltage regulation in single DC-source cascaded H-bridge multilevel converters using phase-shift modulation. In this paper using the phase-shift modulation approach, a new control method for cascaded H-bridge multilevel converters fed with only one independent dc source is

presented [7]. Elena Villanueva (2009), proposed a control of a Single-Phase Cascaded H-Bridge Multilevel Inverter for Grid-Connected Photovoltaic Systems. The topology offers advantages such as the operation at lower switching frequency or lower current ripple compared to standard two-level topologies [8]. B.S. Rair (2015) proposed decoupled control of modular multilevel converters using voltage correcting modules. In this paper CHB, capacitor-clamped and neutral point-clamped topologies are used for medium to high voltage applications [9].T.Sato (2015) proposed enhancement of performance, availability and flexibility of a battery energy storage system based on a modular multilevel cascaded converter. This paper proposed that the single-star bridge cells-based battery energy storage system produces three-phase 3 multilevel voltage waveforms and eliminates both harmonic filter and a complicated zig-zag transformer on ac side [10].

CASCADED H-BRIDGE 7-LEVEL INVERTER

Conventional cascaded multilevel inverter consists of a number of single-phase H-bridge inverters. The CHB inverter with seven to eleven voltage levels has been widely used in high-power and medium-voltage applications. IGBTs are exclusively used as switching devices in these inverters. Among the available multilevel converter topologies, the cascaded multilevel converter constitutes a promising alternative, providing a modular design that can be extended to allow a transformer less connection to the grid [9]. Additionally, this topology features power semiconductors with a lower rating than the standard two-level configurations, allowing cost savings [5]. Last but not the least; multilevel topologies feature several freedom degrees that make possible the operation of the converter even under faulty conditions, increasing, in this way, the reliability of this system. Cascaded H-bridge inverter requires many isolated dc sources.

Normally, each phase of a cascaded multilevel inverter needs ‘n’ dc sources for 2n+1 level. A stepped output voltage and current can be obtained in a cascaded multilevel inverter by cascading many H-bridge inverters. In spite of all these characteristics, the cascaded multilevel topology has also disadvantages, as the strings of PV panels are not grounded and extra measures have to be taken in order to avoid currents due to stray capacitances between the panel and the earth. In order to properly operate a cascaded converter with n cells, the independent control of the dc-link voltages and the control of the grid current are necessary. This task must be accomplished by using the n available actuation signals corresponding to the modulation units of each cell. Several methods have been proposed to the control of this configuration. In the reference signals for the modulation units of each cell are multiplied by a factor that depends on the voltage in each dc link and the power that the corresponding string of PV panels is delivering. Unfortunately, no experimental results are given. Other approaches operate only under equal dc-link voltages. Among the several multilevel converter topologies [2], the cascade H-bridge (CHB) multilevel converter [7] has received special attention due mainly to its modularity, reliability, and feasibility.

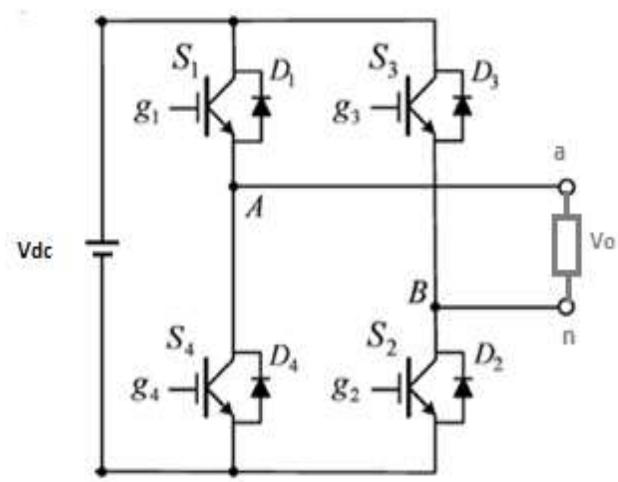

Figure.1 - Single Phase H-bridge Inverter.
Source - High-power Converters and AC Drives, IEEE Press, New Jersey, 2006

Single-phase H-bridge inverter is composed of two inverter legs with two IGBT devices in each leg. The inverter dc bus voltage Vd is normally fixed and its ac output voltage can be controlled by using modulation schemes. On adding another H-bridge in cascade to the existing H-bridge, number of levels increase by two. Hence, three H-bridge inverters are to be cascaded to get a 7-level output. No two switches in the same leg conduct at the same time so as to prevent short circuit across the voltage source. Each voltage source is Vdc and thus the maximum voltage 3Vdc can be obtained with conventional CHB 7-level inverter. 7-level output voltage is obtained having Vdc, 2Vdc, 3Vdc in positive half cycle, zero level, -Vdc, -2Vdc, - 3Vdc in negative half cycle.

In Fig. 2 the schematic diagram of a single-phase 7-level CHB converter, connected as an active rectifier, is shown. Although the proposed method is equally as effective in the inverter mode configuration, in order to test the capability of a DC-Link voltage balancing algorithm and avoid the necessity of isolated high voltage sources, the rectifier configuration is preferred.

A CHB converter is composed of a cascade connection of H-bridge (or full-bridge) single-phase converters, whose ac outputs are combined to reproduce a desired output voltage reference. However, all these H-bridges have separated dc buses, where separate dc supplies or separate capacitors can be connected. In contrast to other topologies, CHB converters have achieved larger output voltage levels in commercial applications [5], and they have shown a better efficiency and dynamic performance [8], all these with a reduced number of switching devices.

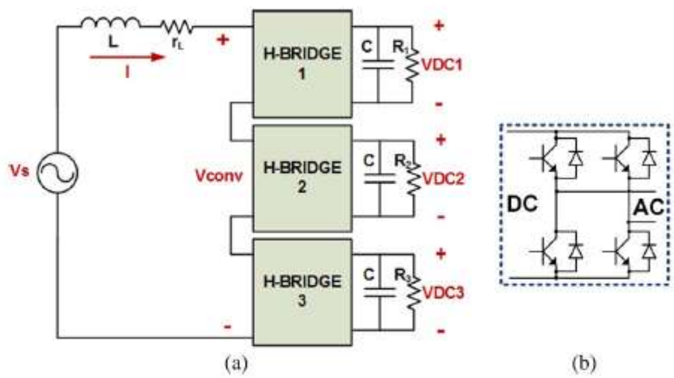

Figure 2:(a) Schematic diagram of a 7-level CHB in active rectifier configuration, and (b) a single HB circuit.

Source - IEEE Transactions on Industrial Electronics Nov.2014

Conventional cascaded H-bridge inverter requires numerous power switches which need corresponding gate drive circuitry. This leads to increase in the complexity of the circuit and also increases the total cost of the inverter.

PROPOSED TOPOLOGY

The proposed topology consists of single phase seven level cascaded h-bridge converter. Cascaded h-bridge converter consists of four cells and two legs. Each leg consists of two devices. In this topology IGBT are used. IGBT is more advantageous than any other power semiconductor devices hence it is beneficial to use IGBT. No two switches in the same leg conduct at the same time so as to prevent short circuit across the voltage source. Each H-bridge produces two voltage levels. On adding another H-bridge in cascade to the existing H-bridge, number of levels increase by two. Hence, three H-bridge inverters are to be cascaded to get a 7-level output. All three H-bridges are connected in series to get seven level single phase cascaded h-bridge converter. The series connection of the cells generates the output voltage waveforms that are synthesized by the combination of each output of the cells at certain switching state. In general, when k H-bridges are connected in series, the output waveforms contains n=2k+1 voltage levels. The Simulink model in MATLAB provides a graphical user interface, user can call the standard library module from where the necessary blocks and components are selected and are properly connected to form the dynamic system model. If power required by the load is greater than power available then extra power will be given by photovoltaic cell through cascaded H-bridge converter. As photovoltaic cell is a form of renewable energy it is advantageous to use photovoltaic cell. The problem of voltage imbalance will be minimized.

CONCLUSIONS

Objective of the proposed work is to design balance control circuit of the single phase seven-level cascaded H-bridge converter. The Cascaded H-bridge topology is one of the best topology for high voltage grid-connected PV system. The efficiency will be increased by using cascaded H-bridge converter. Balance control circuit for single phase seven-level cascaded H-bridge converter will be presented. The grid connected process is controlled using voltage oriented control technique. The system designed will be versatile and flexible. Balance control circuit for single phase seven-level cascaded H-bridge is proposed and the waveform of voltage and current will be studied and analyzed. The series connection of the cells generates output voltage waveforms that are synthesized by the combination of each output of the cell at certain switching state. The problem in the voltage imbalance will be minimized.

ACKNOWLEDGMENT

I am thankful to my guide Prof.M.J. Katira for his guidance and support for this paper. I owe a great to my parents, for their continuous encouragement and moral support.

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