

Cascaded H-BRIDGE Converter for Domestic Applications

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Abstract-- Multilevel inverters have recently found its way in to the high power applications in both domestic and industrial fields with its ability of low switching frequency. Out of all the topologies of a multilevel inverter, the cascaded H-bridge inverter is most commonly used due to its modular topology. This paper presents a five level cascaded multilevel inverter whose dc voltage source is charged by a solar panel. The switching is done by PIC microcontroller. The programming of the microcontroller is done using MPLAB programmer. Topology is designed with minimum size, weight & reduced power losses. The simulation work is done using MATLAB and experimental results have been presented to validate the theory.

Index terms - cascaded H-bridge , MATLAB, multilevel inverters, solar panel.



1. Introduction

Multilevel inverters has gained widespread interest recently. The normal CSIs and VSIs are two-level inverters because the power switches are connected to either the positive or the negative DC bus. Though this method is effective, it creates harmonic distortions in the output voltage, EMI and high dv/dt. This may not always be a problem, but for some applications there may be a need for low distortion in the output voltage. If more than two voltage levels were available to the inverter output terminals, the output which is obtained can be approximated as a sine wave. The concept of multilevel inverters (MLI) does not depend on just two levels of voltage to create an AC signal. Instead several voltage levels are added to each other to create a smoother stepped waveform with lower dv/dt, lesser distortions in harmonics, smaller common-mode voltage and lower switching frequency thereby making it available for high power applications [1]. With more voltage levels in the inverter, the waveform finally obtained becomes smoother.

There are different kinds of topologies of multilevel inverters which is obtained by designing the multilevel circuits in different ways that can generate a stepped voltage waveform and that are suitable for different applications. The available topologies include neutral point clamped, flying capacitor and cascaded H-bridge converters [2]. Diode-clamped multilevel converters are used in conventional high-power ac motor drive applications like in mills, conveyors, fans, etc.

They are also utilized in gas, power, mining, water, chemical industries, etc. Flying capacitor multilevel converters have been used in high-bandwidth high-switching frequency applications such as medium-voltage traction drives. Finally, a cascaded H-bridge multilevel converters have been applied where high power and power quality are essential, for example, active filter, reactive power compensation, static synchronous compensator applications, photovoltaic power conversions, UPS, etc. Besides, one of the growing applications for multilevel motor drives is in the electric and hybrid power trains [3].

This paper presents a five-level cascaded H-bridge multilevel inverter in which each of the level is fed by a solar panel. The simulation is done with the help of MATLAB and hardware implementation details are also included. The first part explains about the cascaded H-bridge inverter. The second part deals with the simulation and its result.

2. H-Bridge Multilevel Inverter

A cascaded H-bridge multilevel inverter differs in several ways from the other multilevel inverters in how it achieves the voltage waveform using separate DC sources, in a modular setup, to create the stepped waveform. The cascaded H-bridges multilevel inverter introduces the idea of using Separate DC Sources (SDCSs) to produce an AC voltage waveform. Each of the H-bridge inverter is

connected to separate DC source's V_{dc} . The AC outputs of each H-bridge inverter is cascaded and an AC voltage waveform is produced. The number of levels in a cascaded inverter is defined by

$$m = 2s + 1 \quad (1)$$

where s is the number of dc sources.

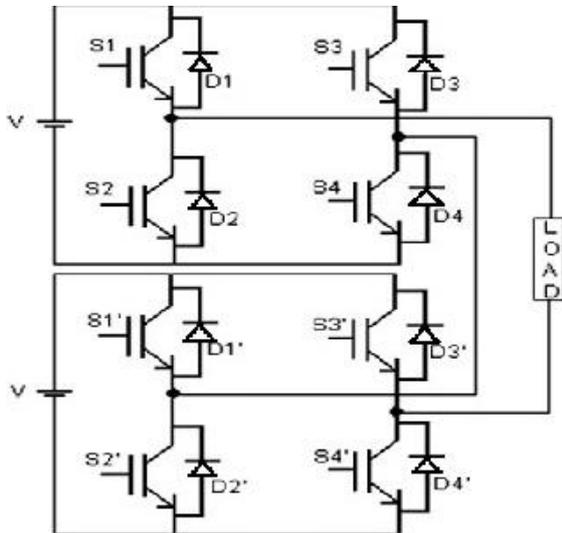


Fig.1 Five Level Cascaded Multilevel Inverter

Fig.1 shows a five-level cascaded multilevel inverter. The ac output of each of the different level H-bridge cells is connected in series to synthesis a multilevel waveform. The so obtained voltage waveform is hence the sum of the inverter outputs. The H-bridge topology can be seen as being made of modules. Every module added in cascade to the already existing levels extends the inverter with two voltage levels. The total output voltage is the sum of the outputs of all the full-bridge modules in the inverter and every full-bridge can create the three voltages $+V_1$, 0 and $-V_1$. It should be noted that the cascaded multilevel inverter is capable of putting out the total voltage magnitude in both positive and negative direction while many other topologies can only put out half the total DC-bus voltage source magnitude. If the inverter is being implemented in active power transfer applications, the voltage sources need to be isolated since there is no common DC-bus to recharge the sources energy content. Renewable energy sources can hence be used to charge each of the DC source. A drawback for the energy / fuel cell applications is however that the sources must be charged individually or through the inverter.

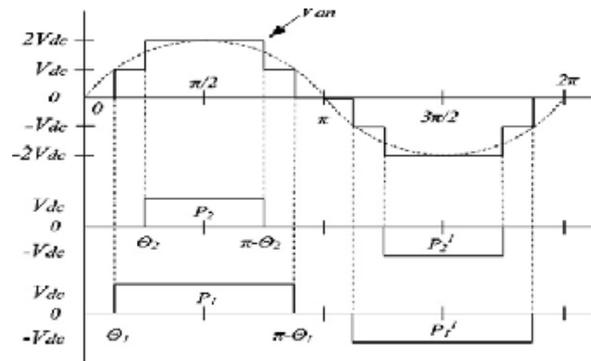


Fig.2 Output Voltage Waveform Of The 5 Level Inverter

3. Simulation

This section presents the simulation results that have been obtained in a two cell CHB converter. Real power semiconductors have been considered with a minimum margin of 0.01 radians between the two consecutive switching angles. The simulation is done using MATLAB. The circuit is as shown in Fig.3. Each of the eight switches are triggered using phase-shifting PWM technique, i.e., a sine wave is compared with a triangular wave to produce the signal which is used to trigger the switches. It should be noted that any PWM technique can be used for the switches.

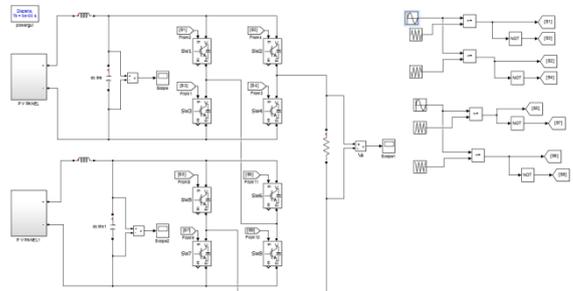


Fig.3 Simulation Circuit

The PV panel which is used has to be designed initially before the simulation. PV modules are the fundamental power conversion unit of a PV generator system. The output of a PV module depends on the cell temperature, solar insulation and the output voltage [4]. Since PV modules exhibit nonlinear electrical characteristics, the designing and simulation of this system requires a reliable modeling. Additionally, mathematical modeling of PV module is continuously updated to enable researcher to have a better understanding of its working [5]. Several proposals have been put forth by various researchers. A behavioral cell model for modeling solar radiance to electricity

conversion and an electrical driver interface for implementing electrical characteristic of power limited systems in power simulations is used here [6].

For the modeling of the PV panel, the following equations are needed,

Thermal voltage equation

$$V_T = k_B T_{OPT} / q \quad (2)$$

Diode current equation

$$I_D = N_P I_S [e^{(V/N_S) + (I_{RS}/N_S)/N V_T} - 1] \quad (3)$$

Load current equation

$$I_L = I_{ph} N_P - I_D - I_{SH} \quad (4)$$

Photo current equation

$$I_{ph} = [k_i (T_{OPT} - T_{REF}) + I_{SC}] I_{RR} \quad (5)$$

Shunt current equation

$$I_{sh} = (I_{RS} + V) / R_{SH} \quad (6)$$

Reverse saturation current

$$I_S = [I_{RS} (T_{OPT} - T_{REF})^3 * q^2 E_g / N k_B * e^{(1/T_{OPT} - 1/T_{REF})}] \quad (7)$$

Reverse current equation

$$I_{RS} = I_{SC} / [e^{(qV_{OC}/k_i c T_{OPT})} - 1] \quad (8)$$

Output power

$$P = VI \quad (9)$$

Where,

- V_T : Thermal Voltage
- V : Operating Voltage
- V_J : Junction Voltage
- V_{OC} : Open Circuit Voltage
- I_{ph} : Photocurrent function of irradiation and junction temperature
- I_S : Reverse Saturation Current of Diode
- I_{SC} : Short Circuit Current
- I : Cell Output Current
- T_{REF} : Reference Operating Temperature of Cell
- T_{OPT} : Operating Temperature of Cell
- R_{SH} : Shunt Resistance of Cell
- R_S : Series Resistance of Cell
- E_g : Energy Band Gap
- N : Ideality Factor
- k_B : Boltzmann constant
- k_i : Current Proportionality constant
- k_v : Voltage Proportionality constant
- q : Electron charge
- N_s : No. of cells in series
- N_p : No. of cells in parallel
- G : Irradiance
- C : No. of cells in Module

With the above parameters, the subsystem is modeled. Fig. 4 shows the simulated output. A five level multilevel output is obtained.

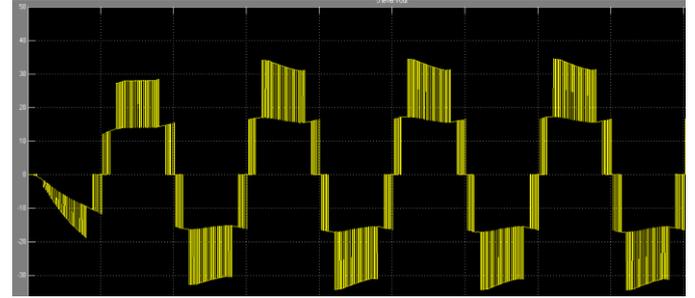


Fig. 4 Output

Using a three-cell topology and three angles per cell, it is feasible to set the amplitude of the fundamental component and to control up to six undesirable harmonic components [7].

4. Conclusion

The proposed cascaded H-bridge multilevel inverter using the DC sources charged from a solar panel was developed. The fundamental switching scheme is employed using the PIC microcontroller. The main advantage of using cascaded H –bridge is that:

- It requires a low number of components per level
- It has modularized structure without clamping components
- There is a possibility to implement soft-switching
- It has simple voltage balancing modulation

The output obtained from the MLI can be utilized for charging batteries, in UPS and other household appliances. By increasing the input voltage source, this inverter can also be used in HEV/EV.

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Pooja Jose has obtained her B.E degree in Electrical and Electronics Engineering from Sathyabama University, Chennai. She is persuing IVth semester, M.Tech(Power Electronics) at Vedavyasa Institute Of Technology, Malappuram, Kerala, India. Her current research interests are in Multilevel Inverters applications, modeling and simulation.

